THE EFFECT OF CONCEPTUAL CHANGE BASED INSTRUCTION ON STUDENTS' UNDERSTANDING OF RATE OF REACTION CONCEPTS

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submitted by **EBRU KAYA** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Secondary Science and Mathematics Education Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen _______________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Ömer Geban _______________
Head of Department, **Secondary Science and Math. Edu.**

Prof. Dr. Ömer Geban _______________
Supervisor, **Secondary Science and Math. Edu.**

Examining Committee Members

Prof. Dr. Ayhan Yılmaz _______________
Secondary Science and Mathematics Education Dept., HÜ

Prof. Dr. Ömer Geban _______________
Secondary Science and Mathematics Education Dept., METU

Prof. Dr. Hamide Ertepınar _______________
Elementary Education Dept., METU

Assoc. Prof. Dr. Esen Uzuntiryaki _______________
Secondary Science and Mathematics Education Dept., METU

Assoc. Prof. Dr. Yezdan Boz _______________
Secondary Science and Mathematics Education Dept., METU

Date: **21/03/2011**

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name: Ebru KAYA

Signature:

ABSTRACT

THE EFFECT OF CONCEPTUAL CHANGE BASED INSTRUCTION ON STUDENTS' UNDERSTANDING OF RATE OF REACTION CONCEPTS

KAYA, Ebru

Ph. D. Department of Secondary School Science and Mathematics Education
Supervisor: Prof. Dr. Ömer GEBAN
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The purpose of this study was to investigate the effects of conceptual change based instruction accompanied by demonstrations (CCBIAD) and gender on 11th grade students' understanding and achievement in rate of reaction concepts, and their attitudes toward chemistry as a school subject compared to traditionally designed chemistry instruction (TDCI). Sixty nine 11th grade students from two classes in a public high school in Ankara participated in this study in the Fall Semester of 2008-2009. These classes were randomly assigned as control and experimental groups. In the control group TDCI was used, while in the experimental group CCBIAD was used as instructional methods.

Rate of Reaction Concept Test, Rate of Reaction Achievement Test, and Attitude Scale toward Chemistry were administered to both groups as pre-tests and post-tests to assess students' understanding of rate of reaction concepts, achievement in these concepts, and attitudes toward chemistry, respectively. Science Process Skills Test was given at the beginning of the study to control students' science process skills. After treatment six students from each group were interviewed to determine their misconceptions about rate of reaction.

The hypotheses were tested by using Analysis of Covariance (ANCOVA) and Two-Way Analysis of Variance (ANOVA). The results show that CCBIAD used a significantly better acquisition of scientific conceptions related to rate of reaction than TDCI. In addition, there was a significant effect of CCBIAD on students' attitudes toward chemistry. There was no significant effect of gender on both students' understanding of rate of reaction concepts and their attitudes toward chemistry.

Keywords: Conceptual Change Based Instruction, Rate of Reaction, Misconception, Demonstration, Attitude toward Chemistry, Science Process Skill

ÖZ

KAVRAMSAL DEĞİŞİME DAYALI ÖĞRETİM METODUNUN ÖĞRENCİLERİN REAKSİYON HIZI KAVRAMLARINI ANLAMALARINA ETKİSİ

KAYA, Ebru

Doktora, Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü
Tez Yöneticisi: Prof. Dr. Ömer GEBAN
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Bu çalışmanın amacı gösteri deneyleriyle desteklenmiş kavramsal değişime dayalı öğretim metodunun geleneksel kimya öğretimine kıyasla 11. sınıf öğrencilerinin reaksiyon hızı kavramlarını anlamalarına, bu konudaki başarılarına ve kimyaya karşı tutumlarına etkisini incelemektir. Bu çalışmaya 2008-2009 güz döneminde Ankara'da bulunan genel bir lisedeki iki kimya sınıfında öğrenim gören altmış dokuz on birinci sınıf öğrencisi katılmıştır. Bu sınıflar kontrol ve deney grubu olarak rastgele seçilmiştir. Kontrol grubunda geleneksel kimya eğitimine dayalı bir öğretim kullanılırken deney grubunda gösteri deneyleriyle desteklenmiş kavramsal değişime dayalı bir öğretim kullanılmıştır.

Öğrencilerin reaksiyon hızı ile ilgili kavramları anlamalarını değerlendirmek için Reaksiyon Hızı Kavram Testi, bu konudaki başarılarını belirlemek için Reaksiyon Hızı Başarı Testi ve kimyaya karşı tutumlarını değerlendirmek için Kimyaya Karşı Tutum Ölçeği her iki gruptaki öğrencilere ön test ve son test olarak uygulanmıştır. Öğrencilerin bilimsel işlem becerilerini belirlemek için çalışmanın başlangıcında her iki gruptaki öğrencilere Bilimsel İşlem Beceri Testi uygulanmıştır.

Araştırmanın hipotezleri Kovaryans Analizi (ANCOVA) ve İki Yönlü Varyans Analizi (ANOVA) kullanılarak test edilmiştir. Sonuçlar, gösteri deneyleri ile desteklenmiş kavramsal değişime dayalı öğretimin geleneksel kimya öğretimi ile kıyaslandığında reaksiyon hızı ile ilgili kavramların anlaşılmasında daha etkili olduğunu göstermiştir. Ayrıca, bu öğretimin öğrencilerin kimyaya karşı tutumlarında anlamlı bir etkisinin olduğu da bulunmuştur. Cinsiyetin hem öğrencilerin reaksiyon hızı kavramlarını anlamalarına hem de onların kimyaya karşı tutumlarına anlamlı bir katkısının olmadığı belirlenmiştir.

Anahtar Sözcükler: Kavramsal Değişime Dayalı Öğretim, Reaksiyon Hızı, Kavram Yanılgısı, Gösteri Deneyi (Demonstrasyon), Kimyaya Karşı Tutum, Bilimsel İşlem Becerisi.

To my dear family

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LIST OF SYMBOLS

CCBIAD: Conceptual Change Based Instruction Accompanied by Demonstrations

TDCI: Traditionally Designed Chemistry Instruction

EG: Experimental Group

CG: Control Group

RRCT: Rate of Reaction Concept Test

RRAT: Rate of Reaction Achievement Test

ASTC: Attitude Scale toward Chemistry

SSPT: Science Process Skill Test

ANOVA: Analysis of Variance

ANCOVA: Analysis of Covariance

$\overline{X}$: Mean

SD: Standard Deviation

F: F Statistic

t: t Statistic

df: Degrees of Freedom

p: Significance Level

MS: Mean Square

SS: Sum of Squares

CHAPTER I

INTRODUCTION

Science education aims to enhance conceptual understanding of students for their performing complex activities such as making scientific explanations (Smith, Blakeslee, & Anderson, 1993). Learning as an active construction of students' conceptions (Nieswandt, 2000) occurs in consequence of the interaction between students' current and new conceptions (Ausubel, 1968; Linn, 1987). Students' existing knowledge and concepts affect their learning of science. However, students might have some difficulties while learning science. These difficulties in understanding scientific concepts stem from the concepts which students bring with them to the classroom before the instruction (Hewson & Hewson, 1983). Students do not enter into a classroom "with a blank slate" (Chi & Roscoe, 2002). They generally have their own conceptual schemes about the subject to be taught. In general, these conceptions of students are different from the scientific ones. The researchers called these conceptions as varied as "misconceptions" (Driver & Easley, 1978), "preconceptions" (Driver & Easley, 1978), "alternative frameworks" (Osborne & Freyberg, 1985), "alternative conceptions" (Abimbola, 1988), "naive beliefs" (Caramaza, McCloskey, & Green, 1981), "children's science" (Gilbert, Osborne, & Fensham 1982) and "intuitive conceptions" (Lee & Law, 2001).

Once misconceptions are integrated into a student's cognitive structure, they become an obstacle in his/her learning. Thus, the student has difficulty in connecting new information into his/her cognitive structure including inappropriate knowledge. In this situation, since new knowledge cannot be integrated to cognitive structure, students have misconceptions about that knowledge (Nakhleh, 1992). Misconceptions which are not consistent with the accepted explanations, meanings, and theories of science are resistant to change (Novak, 1988) because they are meaningful for the students to perceive the world. Learning science meaningfully requires to realign, to reorganize, or to replace students' misconceptions to accommodate new conceptions. Remediation of misconceptions is a slow process which requires time and clarification of concepts with more concrete examples. If teachers are aware of their students' misconceptions related to core chemical concepts, they are likely to design their instruction to address and remediate the alternative conceptions of the students (Thomas & Schwenz, 1998). Therefore, during science instruction, considering students' misconceptions has a key role for promoting conceptual change in students.

The conceptual change model is one of the effective methods for coping with misconceptions and for understanding concepts. The conceptual change model which is based on constructivist notion claims that learning is a process of knowledge construction (Cobern, 1996). Posner, Strike, Hewson, and Gertzog (1982) proposed this model with four conditions for the accommodation phase to occur: Intelligibility, plausibility, fruitfulness, and dissatisfaction with the existing concepts. Intelligibility condition shows whether the student knows the meaning of the conception or not. If the conception is intelligible for the student, s/he can find a way of representing that conception. If the student believes that the conception is true, s/he finds that conception as plausible. Thus, that conception gets consistent and more easily accommodated with his/her previous conceptions. According to the fruitfulness condition, a student should believe that the conception solves other problems and suggests new possibilities and ideas (Hewson & Thorley, 1989). Dissatisfaction is related with changes in status of a conception. If a student does not find the conception as plausible or fruitful, s/he is dissatisfied with this conception. Status of a conception refers to the extent to which the conception has the conditions of intelligibility, plausibility, and fruitfulness. The more a conception meets these conditions, the higher its status (Hewson & Thorley, 1989). To sum up, if the student is presented a more intelligible, plausible, and fruitful concept, s/he can change his/her previous concept (Posner et al., 1982).

Understanding many concepts in chemistry is difficult for most students because of the abstract nature of chemistry (Ben-Zvi, Eylon, & Silverstein, 1986; BouJaoude, 1991). Therefore, students have many misconceptions in chemistry. Research have focused on the following subjects: particulate nature of matter (e.g. Gabel, Samuel, & Hunn, 1987; Griffiths & Preston, 1992; Novick & Nussbaum, 1981), chemical bonding (e.g. Boo, 1998; Taber, 2003), chemical equilibrium (e.g. Gorodetsky & Gussarsky, 1986; Hackling & Garnett, 1985; Wheeler & Kass, 1978), gases (e.g. Benson, Wittrock, & Baur, 1993; Cho, Park, & Choi, 2000), electrochemistry (e.g. Garnett & Treagust, 1992), evaporation, condensation and thermodynamics (e.g. Bar & Travis, 1991), acid and base (e.g. Nakhleh, 1994), heat and temperature (e.g. Harrison, Grayson, & Treagust, 1999).

Reaction rate is an abstract chemical topic, which is also important in learning other fundamental chemical concepts such as chemical equilibrium. Students have misconceptions, thus learning difficulties, in the subject of reaction rate. Since understanding concepts related to reaction rate is crucial in learning other chemical concepts, appropriate teaching strategies should be designed by considering the results of the research about rate of reaction in the literature. Although extensive research related to chemical equilibrium has been carried out, research about students' understanding of rate of reaction concepts is limited (Justi, 2002). Therefore, research needs to be conducted to investigate how students change their misconceptions about rate of reaction.

To overcome students' misconceptions, a large amount of research has explored the effects of several instructional tools based on conceptual change approaches in science, such as concept maps (e.g. Tekkaya, 2003), conceptual change texts (e.g. Sungur, Tekkaya, & Geban, 2001), cooperative learning strategy (e.g. Basili & Sanford, 1991; Bilgin, 2002), computer assisted instruction (e.g. Cetin, 2009; Snir, Smith, & Raz, 2003), analogies (e.g. Bozkoyun, 2004; Dagher, 1994), and etc. However, there is limited research on the effect of demonstration usage based on conceptual change method (e.g. Azizoglu, 2004). Since demonstration is an effective teaching strategy for facilitating students' learning of chemistry, in this study, demonstrations related to rate of reaction subject were used in conceptual change based instruction.

In science education, attitude toward science is another factor affecting students' science achievement as well as students' alternative conceptions or misconceptions. Attitude is an affective concept influencing one's construction of knowledge and action to something (Shrigley, Koballa, & Simpson, 1988). An important reason for examining attitudinal constructs in science education is to be able to understand the ways in which they affect student learning in the cognitive field. Students' interest is likely to be positively correlated with their achievement in science understanding (Simpson, Koballa, Oliver, & Crawley, 1994).

The relationship between attitude and achievement is influenced by contextual factors, including classroom organization, teacher authority, the nature of classroom academic tasks, and evaluation structure. These contextual factors may serve to strengthen the relations between attitudinal constructs and science learning as well as to weaken them (Pintrich, Marx, & Boyle, 1993). The present study also investigates the effect of conceptual change based instruction accompanied by demonstrations on students' attitudes toward chemistry.

1.1 Purpose of the study

The purpose of the study is to investigate the effect of conceptual change based instruction accompanied by demonstrations on students' understanding of rate of reaction concepts and their attitudes toward chemistry as a school subject when compared to traditional designed chemistry instruction.

1.2 Significance of the Study

Students' misconceptions are a barrier to their learning and understanding of chemistry topics. Since students do not appropriately structure fundamental chemistry concepts, they are face with difficulties in understanding more advanced concepts (Nakhleh, 1992). Therefore, it is of importance to remedy students' misconceptions in chemistry learning. However, traditional instruction is not an appropriate instructional method since students' misconceptions are not taken into consideration during the instruction. In this study, in order to eliminate students' misconceptions related with rate of reaction, conceptual change based instruction was designed and applied to students. Teaching for conceptual change requires a teaching strategy in which students' existing conceptions and misconceptions brought into classroom are taken into consideration and in which students find new conceptions offered more intelligible, plausible, and fruitful (Hewson & Hewson, 1983). According to this strategy, the subject of reaction rate was presented to the students by considering the conditions of accommodation phase (Posner et al., 1982). Different types of instructional strategies can be used in line with the conceptual change approach in teaching of science. In this study, demonstrations which help students better understand the concepts and which foster their interests in chemistry are used based on conceptual change based instruction.

Rate of reaction as a highly structured topic is a central part of chemistry curriculum (Cachapuz & Maskill, 1987). Therefore, comprehension of concepts with respect to rate of reaction and factors affecting it has a key role in learning of chemistry (Ragsdale, Vanderhooft, & Zipp., 1998). Because of the abstract nature of this concept, students are faced with difficulties, and also they have some misconceptions about the rate of reaction concepts (deVos & Verdonk, 1986; Justi, 2002). Students are required to conceptualize descriptive, particulate, and mathematical modeling regarding chemical kinetics and the interrelations between them in order to improve their understanding of reaction rate concepts (Cakmakci, Donnelly, & Leach, 2003). Therefore, it is important to define and describe these misconceptions before the actual instruction, and also special instructional strategies have to be designed to show students that scientific conception is more useful than their existing conceptions.

In addition, rate of reaction concepts is an essential prerequisite for some chemistry concepts, especially chemical equilibrium concepts. Therefore, students' prior knowledge of rate of reaction is important to further understand of the chemistry concepts. In educational research, although there has been substantial research on students' understanding of chemical equilibrium concepts, there is limited research related to students' understanding of rate of reaction concepts. (e.g. Cakmakci, 2005; Gorodetsky & Gussarksy, 1986; Van Driel, 2002). The concepts related to rate of reaction and the factors affecting this are important in basic chemistry curriculum. In spite of their importance, it is surprising that the misconceptions about rate of reaction and the development of students' understanding of this subject has not been much of a focus in educational research over many years. Therefore, in this study, students' misconceptions about rate of reaction were investigated, and in order to develop students' understanding of this topic, conceptual change based instruction was applied.

As a construct of the affective domain in science education, attitude has been examined in many research studies focusing on the relationship among instruction, achievement and attitude (e.g. Francis & Greer, 1999; George, 2000; Rennie & Punch, 1991). The results of these studies provide evidence that there is a relationship among these constructs. These research studies show that the type of instruction affected students' attitudes toward science as a school subject and that the students' attitudes had potential to affect students' motivation, interest, and achievement in science (Chambers & Andre, 1997; Parker, 2000; Rennie & Punch, 1991). Furthermore, literature points to the fact that the instruction based on conceptual change approach had a positive effect on students' understanding of science concepts and caused significantly higher positive attitudes toward chemistry as a school subject than the traditionally designed chemistry instruction (Bozkoyun, 2004; Cam, 2009; Uzuntiryaki, 2003). Since students' attitudes is an important construct in science education, in this study, the effect of conceptual change based instruction on students' attitudes toward chemistry as well was investigated.

In sum, the results of this study are likely to contribute valuable insights into teaching and learning of rate of reaction concepts regarding conceptual change based instruction, and students' attitudes towards chemistry. It also hopes that this study, with its methodology, will set an example for teachers, students, curriculum developers, and other researchers. Chemistry teachers can develop and apply instructions based on conceptual change model and arrange some activities to assist their students' learning of rate of reaction concepts. Thus, students' understanding of this subject would be easier and more meaningful.

1.3 Definition of the Key Terms

The definitions of the key terms are given in the following:

Misconception: the existing conceptions which are different from the scientifically correct ones (Driver & Easley, 1978).

Assimilation: the process in which mental structure of a person does not change while in the accommodation process it does. In the assimilation phase, students use their previous concepts while learning new concepts (Chi & Roscoe, 2002).

Accommodation: the phase in which students reorganize or change their existing concepts when students' existing concepts are insufficient while learning new concepts (Chi & Roscoe, 2002).

Conceptual change based instruction: an effective instruction for eliminating students' misconceptions in science. In this instruction, the concepts should be presented to students as intelligible, plausible, and fruitful (Posner et al., 1982).

Traditional instruction: the instruction in which teachers mainly use lecture and discussion methods, students do not actively participate in classroom discourse, and teachers do not consider students' misconceptions during instruction.

Science Process Skill: ability of students in solving complex problems in science.

Attitude toward chemistry: a person's liking or disliking of chemistry (Nieswandt, 2007), or having a positive or negative feeling (Koballa & Crawley, 1985) about chemistry.

CHAPTER II

REVIEW OF LITERATURE

The review of literature chapter consists of five parts. In the first part, the misconceptions related to rate of reaction determined in the literature are presented. The second part reviews the literature related conceptual change method with its theory and applications. In the next part, demonstration which is used by accompanying with conceptual change method in this study is presented by reporting the related research in science education. The fourth part presents the literature with respect to attitude affective domain since this study has investigated the effect of conceptual change based instruction on students' attitudes toward chemistry. Finally, research regarding the effect of gender on conceptual change and attitudes toward chemistry is reviewed.

2.1 Misconceptions related to Rate of Reaction

The subject of rate of reaction is connected with the subject of chemical equilibrium because an understanding of rate of reaction concepts is a prerequisite for the understanding of concepts regarding chemical equilibrium. In addition, some misconceptions in chemical equilibrium determined in the literature are also related to rate of reaction concepts. Therefore, in this part, both the research on students' misconceptions with respect to chemical equilibrium concepts and those with respect to rate of reaction concepts are reviewed.

Chemical equilibrium is one of the most difficult concepts in chemistry for the students to understand (Wheeler & Kass, 1978). The sources of students' misconceptions in this concept result from its abstract nature (Ben-Zvi et al., 1986;

Huddle & Pillay, 1996) and words used from everyday language (Bergquist & Heikkinen, 1990). Students perceive chemical equilibria as a static process not a dynamic process. The reason of this perception by students might be their belief that chemical reactions are observable phenomena and nothing occurs during a chemical equilibrium (Wheeler & Kass, 1978).

Some research on teaching and learning of chemical equilibrium have focused on students' conceptions related to chemical equilibrium (e.g. Quilez-Pardo & Solaz-Portoles, 1995), some have focused on students' frameworks in chemical equilibrium (e.g. Gussarksy & Gorodetsky, 1990; Maskill & Cachapuz, 1989), some have dealt with students' usage of Le Chatelier's principle (e.g. Banerjee, 1995), and some have investigated this subject from quantitative aspects (e.g. Hackling & Garnett, 1985; Huddle & Pillay, 1996).

Hackling and Garnett (1985) conducted a research in order to identify students' misconceptions in chemical equilibrium. The sample of that study consisted of thirty 12^{th} grade Western Australian chemistry students who were 17 years old. The researchers focused on students' difficulties in discriminating completion reactions and reversible reactions. They also argued about students' previous experiences regarding chemical reactions as the source of the misconceptions in this subject (e.g. some exothermic reactions or the reaction between magnesium ribbon and dilute acid). Some misconceptions were determined through interviews with students.

In their study, Wheeler and Kass (1978) aimed to determine students' misconceptions in chemical equilibrium and to explain the relationship between students' chemistry achievement and these misconceptions. They used Misconception Identification Test (MIT) consisting of 30 multiple choice items related to the factors affecting the equilibrium to identify students' misconceptions in chemical equilibrium. The misconceptions addressed in this test were related to the difference between mass and concentration, the difference between rate and extent of a reaction, constancy of the equilibrium constant, misuse of Le Chatelier's principle, constant concentration, and factors affecting equilibrium state of a chemical reaction. Ninety-nine 12^{th} grade chemistry students in four classes as the sample of the study were administered MIT, Chemistry Achievement Test, performance tasks, and a written test. The results of this study show that students' misconceptions in chemical equilibrium affect their chemistry achievement. The researchers suggest the teachers that both quantitative and qualitative examples related to chemical equilibrium, and graphical representations for the concepts of constant concentration and the equilibrium constant should be used for students' better understanding.

Some of the misconceptions with respect to chemical equilibrium selected from the literature are:

- The rate of the forward reaction increases with time from mixing reactants until equilibrium is established (Hackling & Garnett, 1985).
- At equilibrium, if conditions are changed, the rate of the favored reaction can be increased while the rate of the other reaction decreases (Hackling & Garnett, 1985).
- The rate of the forward reaction increases as a function of time. The rate of a chemical reaction increases as the reaction gets underway (Hackling & Garnett, 1985).
- The concentration of reactants equals the concentration of products at equilibrium (Gage, 1986).
- No discrimination between reactions go to completion and reversible reactions (Wheeler & Kass, 1978).
- Belief that the forward reaction goes to completion before the reverse reaction commences (Wheeler & Kass, 1978).
- Failure to distinguish between rate (how fast) and extent (how far) of reaction (Wheeler & Kass, 1978).
- Confusion regarding amount and concentration (Bergquist & Heikkinen, 1990).
- Lack of awareness of the dynamic nature of the chemically equilibrated state (Gorodetsky & Gussarsky, 1986).
- Equating arrow length to the rate of the reaction (Lingwood, 1993).
- The use of everyday terms, "shift", "equal", "balanced" conjure of different visual ideas to students from those intended by the teacher. "Equilibrium" especially is seen as the firmly held concept of a static two-sided picture (Bergquist & Heikkinen, 1990).

In their study, Van Driel, deVos, Verloop, and Dekkers (1998) address that "the dynamic nature of chemical equilibria requires students to assume that two opposite chemical reactions are taking place in spite of the fact that this cannot be deduced from observations" (p. 380). Therefore, students are required to change their initial conceptions about chemical reactions. These changes suggested by Van Driel et al. (1998) are presented in the following table:

Table 2.1 Chemical Reaction Concepts Before and After the Introduction of Chemical Equilibrium

The chemical reaction concept in introductory courses	The chemical reaction concept after the introduction of "chemical equilibrium"
A chemical reaction takes place in one direction only, that is, reactants are converted into products. Although the chemical elements are conserved during this process, the products are obtained cannot be directly retransformed into the original reactants.	Many chemical reactions appear to be reversible, that is, the conversion of reactants into products may be reversed by a simple intervention (e.g. heating the reaction vessel or changing its volume).
A chemical reaction always proceeds to completion, that is, all reactants are completely converted as long as they are present according to a fixed mass ratio.	In a state of chemical equilibrium, a chemical reaction does not proceed to completion, that is, all reactants and products are present in the equilibrium system.
A chemical reaction is associated with changes at a macroscopic level, that can be either observed directly (e.g. color change) or with the aid specific instruments (e. g. change of melting point).	In a system at chemical equilibrium, all macroscopic properties are constant. Nevertheless, two opposite reactions are assumed to take place at equal rates, thus cancelling each other's observable effects. Therefore, a chemical equilibrium is called dynamic.

The aims of the study conducted by Van Driel et al. (1998) were to identify reasoning types of the students and to develop teaching strategies for promoting conceptual change. As a pilot study, in order to identify students' preconceptions, a questionnaire was administered to 90 students in groups of three or four students. There were 26 groups in total in the pilot study. Data was gathered by using audiotapes in classroom discussions from 8 groups of them. By using the results of this pilot study, an experimental course was designed. The main study was carried out in three research cycles. In each cycle, the designed experimental course was implemented. Data from audiotapes of classroom discussions and students' written responses were analyzed. The researchers classified students' ways of reasoning according to themes of reversibility, incomplete conversion, and dynamic nature of equilibrium. These ways of reasoning were identified as explanatory model for the concept of dynamic chemical equilibrium and corpuscular notions model. With respect to promoting conceptual change, the researchers argue the anomalous data from the experiments in the course promoted dissatisfaction among students' with their preconceptions and helped to change such conceptions by students. Furthermore, they discuss the effect of motivation on students' conceptual change (Pintrich et al., 1993).

In order to develop students' conceptions of chemical reactions through the introduction of chemical equilibrium and chemical kinetic concepts, Van Driel (2002) carried out a research. The purpose of his study was to identify reasoning types used by students when chemical equilibrium and chemical kinetics are introduced to them. The researcher selected the 10th grade chemistry classes in twelve secondary schools in the Netherlands as the sample of the study. He used conceptual change strategies including tasks to challenge students' misconceptions, small group discussions, and hands on experiments. The results of this study show that students have difficulties related to reasoning in corpuscular terms. The study also points out that "students can gradually learn to become more proficient in using corpuscular models as explanatory tools" (Van Driel, 2002, p. 211). The misconceptions identified in this study are:

- Fewer particles (per unit of volume) would lead to fewer collisions (per unit of time).
- In a dilute solution, particles are at larger distances from each other.
- When fast moving particles collide with each other, it is very likely that these particles will bounce back without a change or reaction.
- The molecules would not have enough time to exchange atoms.

Since the subject of chemical kinetics is important for understanding chemical reaction processes, chemistry kinetics is included in both school and university levels chemistry curriculum in many countries (Justi, 2002). Students have challenges related to chemical kinetic concepts. “The notion of “reaction rate” requires students to understand that it takes time for a chemical conversion to proceed, and that this time is influenced by factors such as the temperature of the system and the concentrations of the reacting substances.” (Van Driel, 2002, p. 205). Justi (2002) emphasizes that understanding of chemical kinetics requires integration of conceptual understanding of many basic concepts such as particulate nature of matter, and the interactive and dynamic aspects of chemical reactions. However, when compared to chemical equilibrium, there is limited understanding about students’ learning of chemical kinetics.

Chemical kinetics is formed in two different aspects: empirical, because of “empirical framework of relations used to describe the interrelation of experimentally accessible parameters, such as reactant concentration and time” (Logan, 1984, p. 191), and theoretical because of “equations that emerge from the various theories of reaction kinetics” (Logan, 1984, p. 191). This complex structure of chemical kinetics is likely to cause teachers to meet difficulties in teaching this subject to their students. Furthermore, the difficulties in learning and teaching reaction kinetics result from mathematical problems (e.g. problems related calculation) and interrelation between chemical kinetics and thermodynamics (Logan, 1984).

Like the topic of chemical equilibrium, students have misconceptions regarding rate of reaction. With respect to the effect of change in temperature on the rates of forward and reverse reactions, many students were found to believe that the rate of the reverse reaction was increased while the rate of the forward reaction was decreased. Students think that the particles would collide less when the temperature increases “because the particles would bounce back” (Van Driel, 2002, p. 210). Students’ misconceptions related to the effect catalyst on a reaction in equilibrium are likely to be due to the students’ limited understanding of the reaction pathway and transition state for the forward and reverse reactions. Some students have difficulties in comprehending “the relationship between the consumption of reactants and formation of products in a chemical reaction” (Hackling & Garnett, 1985, p. 212).

Cachapuz and Maskill (1987) investigated word association tests for explaining how the students from different achievement levels understood reaction kinetics. The researchers designed an instructional text including the reaction between hydrochloric acid and zinc and the factors affecting the rate of this reaction in order to introduce rate of reaction concepts to 48 students from two mixed-ability classes at an English comprehensive school. The students with mean age of 14.5 were in their fourth year. In order to categorize students in terms of their achievement levels, the students were administered an achievement test consisting of 16 multiple choice items and a word association test including 14 stimulus words such as collision, concentration, time, and surface as pre-test and post-test. Pre-test results of the achievement test indicated that there was no conceptual difference between high and low achiever students. With respect to post-test achievement scores, the results point out that low achiever students showed no conceptual changes however high achiever students had more conceptual growth and structuring. The "collision" concept was detected as the key concept for the high achiever students not for the low achievers. In addition, this study addresses the importance of word association tests for the teachers to control students' concept learning in science classrooms.

Cakmakci et al. (2003) investigated students' understanding of the relationships between concentration and reaction rate in Turkey. Some written tasks were given to the students. Also, some students were interviewed to get further information related to their ideas on chemical kinetics. Analyses of the data from written tasks and interviews show that many students have misconceptions and difficulties in understanding the relationships between concentration and reaction rate. In addition, the analysis results show that the students did not use "particulate" and "mathematical" modeling frequently and effectively.

How catalyst affects rate of reaction is incorrectly presented with a diagram (Haim, 1989) and explanations in textbooks (Copper & Koubek, 1999). Haim (1989) emphasizes that these kinds of diagrams which do not present enough information about the mechanism of a reaction might give rise to misunderstandings by the students. For example catalyzed and uncatalyzed reaction occur through the same reaction mechanism (in these diagrams, generally one step mechanism is shown). These diagrams are also an obstacle to understand the most important feature of catalyzed reactions that include sequences of several activated complexes and intermediates. Therefore, he argues that the explanation related to the effect of catalyst on reaction rate might be a reason for students' limited understanding and misconceptions on this subject. He proposes, as a reasonably good explanation of catalyst, that the addition of catalyst results in the creation of new and efficient reaction pathways for the transformation of reactants into products.

In the literature, some analogies for teaching chemical kinetics have been proposed. These analogies vary such as verbal (e.g. Olney, 1988), pictorial (e.g. Fortman, 1994), personal, bridging, and multiple analogies (e.g. Last, 1983, 1985). Some analogies related to chemical kinetics in the literature have deficiencies in terms of the relationship between analogs and their targets (e.g. "doing the dishes" analogy to rate determining step developed by Last (1983), "car parks" analogy to the effect of concentration and temperature on reaction rate developed by Fortman (1994).

Justi and Gilbert (1999) have proposed eight historical models for chemical kinetics by adopting Lakato's Theory of Scientific Research Programmes as the analytical approach. The brief explanations of these models are as follows. The anthropomorphic model based on anthropomorphical conception of matter viewed chemical reactions as transformation in materials and reaction rate as readiness for a transformation to occur. The affinity corpuscular model, which is the first to make predictions about rate and likelihood of a reaction, explained reaction rate based on different degrees of affinity of particles and its readiness to occur. The first quantitative model mathematically explained reaction rate as proportional to the number of particles reacting in a given time. The mechanism model addressed the relationship between reaction rate and mechanism, and the effect of catalysts. The thermodynamics model which pointed out the relationship between temperature and reaction rate viewed chemical reaction as a process in which reacting molecules collided with sufficient energy. The kinetic model which explained the proportional collisions between molecules during a chemical reaction made a contribution to a better understanding of how chemical reaction occurred and why different reactions occurred at different rates. The statistical mechanics model dealt with statistical distribution of molecular speeds and explained a critical energy for chemical reactions to occur. This model argued that reaction rate was proportional to the concentration of activated complexes. The transition state model was established to overcome the limitations of the previous models about chemical kinetics in order to form a better relationship between thermodynamics and kinetics variables. This model enhanced a significant contribution especially for the understanding of the mechanisms of catalyzed reactions. Justi and Gilbert (1999) emphasize that these historical models should be included in curriculum for students to have better understanding of chemical kinetic concepts.

One of the sources of students' difficulties in chemical kinetics could result from their misunderstandings related to chemical reactions at the molecular level. In their study, Justi and Ruas (1997) investigated the effect of students' views about the nature of matter on their learning of chemical kinetics. Before instruction of chemical kinetics subject, the researchers investigated students' views about nature of matter, chemical reaction concept, and how a reaction occurs. During the instruction of chemical kinetics, by considering students' prior knowledge about this subject, they investigated students' ideas used so as to explain the reason of chemical reactions at different rates. They found that most of the students in the sample of the study could not understand or use the ideas of the particulate model of matter. In order to explain why chemical reactions occur at different rates, many of the students used collision particle model incorrectly rather than using the particulate model of matter. The results show that students who had a continuous and static view of matter could achieve to produce a coherent model of chemical kinetics because of their previous views on this topic which changed through the instruction emphasizing important aspects of chemical kinetics.

Another study was conducted by Garnett, Garnett, and Hackling (1995) in order to identify some misconceptions of secondary students' about chemical kinetics. They argue that such ideas of students on chemical kinetics are evidence for students' limited understanding of particulate nature of chemical reaction. The misconceptions identified in their study are:

- The forward reaction rate increases as the reaction gets going.
- The forward reaction rate always equals the reverse reaction rate.
- The forward reaction is completed before the reverse reaction commences.

- When equilibrium is reestablished after a disturbance, the rates of the forward and reverse reactions will be equal to those at the initial equilibrium.
- A catalyst can affect the rates of the forward and reverse reactions differently and hence leads to a different equilibrium yield. (Garnett et al., 1995, p. 81).

Calik, Kolomuc, and Karagolge (2010) conducted a study to investigate the effect of conceptual change based instruction on students' understanding of rate of reaction concepts. The sample of their study consisted of 72 students from two intact classes. Mainly, they used animations regarding rate of reaction concepts in their study. The result of their study shows that conceptual change based instruction was effective in overcoming students' misconceptions and storing their newly structured knowledge in their long-term memories. Similarly, Bozkoyun (2004) examined the effect of conceptual change based instruction on students' understanding of rate of reaction concepts. He used analogies related to rate of reaction concepts during conceptual change based instruction. The results point out that the students who were applied this instruction had better understanding than those who were applied traditionally designed chemistry instruction.

2.2 Conceptual Change Model

Students' previous knowledge has a crucial role in their learning because learning is not just the accumulation of information. Learning as conceptual change is an "active, interactive, connective process requiring changes of different kinds such as addition, linkage, rearrangement, and exchange" (Hewson, Beeth, & Thorley, 2003, p. 199). Posner et al. (1982) proposed a model of learning as conceptual change. The components of the conceptual change model are "status", the conditions which are necessary for accommodation phase of conceptual change, and "conceptual ecology".

Status shows the degree to which a person knows and accepts a conception. Intelligibility, plausibility, and fruitfulness of a conception determine its status. Conceptual ecology, which is the context of conceptual change occurring, deals with all the knowledge of a person. According to conceptual ecology, a person holds information, recognizes that it consists of different kinds, focuses attention on the interactions within this knowledge base, and identifies the role that these interactions play in defining niches that support some ideas (raise their status), and discourage others (reduce their status). Learning a concept means that a student has raised the status of that concept within the context of the student's conceptual ecology. Different research exists on the status of students' conceptions. Conceptual change language was not explicitly used in some of studies (e.g. Treagust, Harrison, & Venville, 1993) while in some (e.g. Beeth, 1993) it was.

Posner et al. (1982) classify phases of conceptual change as "assimilation" and "accommodation". Hewson (1981) calls the assimilation phase "conceptual capture" and the accommodation "conceptual exchange". Chi and Roscoe (2002) define assimilation as the process in which the mental structure of a person does not change while in the accommodation process changes occur in a person's mental structure. In the assimilation phase, students use their previous concepts while learning new concepts. When students' existing concepts are insufficient while learning new concepts, they reorganize or change their existing concepts. This phase is referred to as accommodation (Posner et al., 1982). The conditions for accommodation to occur are as follows:

1. Dissatisfaction with existing conceptions: The student who faces with a new conception must be dissatisfied with his/her existing conceptions in order to consider this new concept. Anomaly, which is the major source of dissatisfaction, exists when a person has difficulty in understanding something. Because anomalies give rise to cognitive conflict, the student is dissatisfied with a new conception. Demonstrations, problems, and labs are the activities that are used to create cognitive conflict in students.

2. Intelligibility of a new conception: A new conception must be intelligible for the student to comprehend it. If the student can understand scientific terms and symbols, and identify a given text or theory, this shows the intelligibility of that new concept for the student.

3. Plausibility of a new conception: Plausibility as a result of consistency of the concepts means that the student can solve the problems related to that concept. The conditions for plausibility of a concept are:
    - Consistency with one's existing metaphysical beliefs and epistemological commitments
    - Consistency with other theories or knowledge
    - Consistency with past experience
    - Creation images for the concept
    - Capability of solving problems.

    Models, metaphors, and analogies should be used to provide intelligibility and plausibility of a new concept for the students.

4. Fruitfulness of a new conception: A new concept must also appear fruitful for new inquiry areas. Thus, it suggests "the possibility of a fruitful research program" (Posner et al., 1982, p. 214).

Conceptual change is an effective method in eliminating students' misconceptions. Chi & Roscoe (2002) define misconceptions as miscategorizations of concepts across ontological categories. In their study, they have argued why misconceptions are difficult to change. They state that if students are not aware of their misconceptions or the necessity of changing them, these misconceptions are resistant to change. Teachers can provide some explanations or demonstrations to their students in order to make them aware of their misconceptions. Teachers use a variety of teaching strategies that promote conceptual change in their students. Minstrell (1985) suggests some instructional principles such as engaging students' existing conceptions, using laboratory activities or other classroom activities that are inconsistent with students' existing conceptions, encouraging students to solve unclear points emerging in classroom discussion, and giving students similar contexts to use their new ideas.

All these strategies are somehow consistent with the conditions for conceptual change. Dissatisfaction with existing conceptions might be created by making students aware of their own ideas, asking for explanations for events, and designing an environment for discussing misconceptions. Plausibility of a new conception can be achieved by identifying frameworks for the new idea and using analogies and metaphors, judging the consistency of the new conception with other theories and ideas; and stressing that this new conception has a potential to explain related phenomena or to solve questions about those phenomena. Fruitfulness of a new conception means the extent to which it helps explain unfamiliar phenomena and leads to new insights.

Teaching for conceptual change refers to a group of teaching models rather than a specific teaching model and meets guidelines consistent with the conceptual change model. Students' knowledge prior to instruction is of great importance in teaching for conceptual change. Personal constructivist approaches on conceptual change consider the person who experiences the conceptual change process. From this perspective, what important elements of a person's conceptions represent and how these representations are used are the key points in conceptual change (Hewson & Thorley, 1989).

Another approach deals with the whole individual rather than just with a person's cognition. For example, Pintrich et al. (1993) suggest general motivational constructs to mediate the process of conceptual change. They also discuss the importance of classroom contextual factors which moderate the relations between student's motivation and conceptual change. They argue that the conceptual change model which is based on only student's cognition without considering the role of student's motivational beliefs and classroom contextual factors in the process of conceptual change results in some difficulties in applying this model.

Champagne, Gunstone, and Klopfer (1985) propose a teaching strategy based on ideational confrontation. This strategy includes providing opportunities to students for arguing their ideas about the situation presented and thus awareness of their existing conceptions, presenting the scientific explanation about the situation, and finally creating a discussion environment to compare students' existing conceptions and scientific conceptions. Roth, Anderson, and Smith (1987) proposed a teaching strategy which includes eliciting students' misconceptions, making explanations, probing after student responses, creating a discussion environment, and practicing.

Smith et al. (1993) examined the use of teaching strategies associated with conceptual change model in learning science through a study of thirteen 7^{th} grade science teachers. Teachers were given some instructional materials and training sessions. Students in classes in which teachers used these instructional materials were more successful in post-tests than those in classes where these materials were not provided by teachers.

Similarly, Hewson and Hewson (1983) conducted a study to investigate the effect of instruction based on conceptual change strategy on students' understanding of mass, volume, density, and relative density concepts. The sample used in this study was ninety 9^{th} grade students with ages ranging from 13 to 20 years with a mean of 16. There were experimental and control groups in the study. In the experimental group, they used conceptual change based instruction. For this aim, they developed some instructional materials such as experiments, discussion, demonstrations, and worksheets by considering students' misconceptions. These materials were used in the experimental instruction and also students' misconceptions were addressed during the instruction. On the other hand, they used traditional instruction in the control group. Before the instruction, all students in both groups applied pre-test, and after instruction they applied post-test. According to pre-test analysis results, there was no significant difference between the scores of the students in both groups. The analysis based on differences between the pre-test and post-test scores shows that the experimental group gained more scientific conceptions and lost more alternative conceptions than the control group.

Hewson et al. (2003) classify some guidelines for teaching conceptual change as ideas, metacognition, status, and justification. In the instruction based on the conceptual change model, teachers should take into consideration students' ideas explicitly while in common practice teachers do not do this. Another issue is that students' ideas should be considered similarly with teacher's idea. This allows the student to choose among different ideas during discussions in classroom discourse.

Metacognition is the awareness and control of a person's own learning (Baird, 1990). The metaconceptial activities such as making explanations on a phenomenon commenting on that explanation, using arguments in order to support or challenge the ideas mentioned in a classroom discourse are used during the process of conceptual change (Hewson, 1991).

Cognitive conflict is a major process in conceptual change. For this process, firstly, students are enhanced to be aware of their existing conceptions and then they are provided cognitive conflicts through some "discrepant events" which are inconsistent with students' previous conceptions. Wiessner (1995, as cited in Nieswandt, 2000) used cognitive conflict strategy in his research. The results of the study show that students' understanding of optic concepts was low, which, according to the researcher is due to lack of experiments that help students to differentiate their previous conceptions and scientific conceptions.

Nieswandt (2000) conducted a study in order to improve students' understanding of basic chemical concepts. The aim of his study was to assess the degree to which students accept the scientific concepts and use them for interpreting the phenomena. The sample of the study consisted of 81 students from four 9th grade classes at four different schools. He developed a chemistry course including six units aimed at making students aware of their previous conceptions and presenting discrepant events to provide cognitive conflict in their mind. Each teaching unit included discussion on students' everyday conceptions about the topic and a planned cognitive conflict by confronting students with a phenomenon that they cannot explain with their prior knowledge. The data was collected through a questionnaire. The results of data analysis indicate that students changed their everyday conceptions to the scientific conceptions in some topics. In addition, some students had a mixture of scientific and everyday conceptions about the topics covered in the study.

Conceptual change is a slow process which is "revision of an initial conceptual system through the gradual incorporation of elements of the currently accepted scientific explanations" (Vosniadou, Ionnides, Dimitrakopoulou, & Papademetriou, 2001, p. 391). Students should be encouraged to be aware of their existing conceptions during conceptual change process. Students come to classroom with their prior knowledge, not with an empty brain. Considering students' prior knowledge has implications for science instruction such as designing instruction by taking into account students' prior knowledge, making students aware of their existing conceptions, ensuring students to understand the limitations of their previous conceptions and explanations. If new knowledge is consistent with the person's existing knowledge, it can be adopted into the person's conceptual structure. Even if this kind of knowledge is presented to students just as a fact without explanation, students can understand that easily. On the other hand, if new knowledge is not consistent with the students' previous knowledge, it should be presented to students with detail explanations to make it clear for their conceptual structures. Thus, students' conceptual structures will go through a restructuring process.

Another research was conducted by Vosniadou et al. (2001) in order to teach mechanics based on conceptual change process to 5^{th} and 6^{th} grade students. The students studied in small groups and then presented what they studied to the other students in the classroom. In addition, the students had a chance to use models, representational symbols and measurements. The researchers found significant differences between the experimental and control groups with respect to their pre and post-test results. With these results, they also had evidence for their claim that experimental learning environment would give rise to promote conceptual change (understanding the concepts). They also conducted interviews to get detailed information about the conceptual change environment. Through this study, the researchers also stress the importance of students' prior knowledge, presuppositions in learning science concepts.

Learning occurs as a construction of new knowledge by the learners in an active way (Resnick, 1983). The learners carry out this process by evaluating and interpreting new knowledge with their existing knowledge in order to make sense of this knowledge for themselves. Thus, the learners restructure their existing conceptions while accepting new knowledge which is based on scientific conceptions (Hewson & Hewson, 1988).

Teachers should diagnose their students' prior knowledge about the topic by administering a pre-test or asking questions to them during the instruction. Teachers should provide appropriate environments through the instructional strategies for the students to clarify their own previous conceptions and become dissatisfied with them. The concepts should be explained to the students by using a demonstration, laboratory session, or a questioning activity in order to make them plausible for the students. And finally the students should be provided opportunities to apply new conceptions to different examples in order to make them fruitful for the students.

The aim of the study by Niaz, Aguilera, and Maza (2002) was to facilitate conceptual understanding of freshman general chemistry students with respect to atomic structure. 160 freshman students from six sections of General Chemistry I course participated in this study. Three sections were assigned as experimental groups and the other three sections as control groups. At the beginning, Thomson, Rutherford, and Bohr Atomic Models were instructed based on traditionally designed method to both group students. After this traditional instruction, the experimental group students discussed six items which have alternative responses related to three atomic models. The students argued on the response they selected for every item during the discussion. Three weeks after this activity, students in both groups had a monthly exam on this subject, and three weeks after this exam, they had a semester exam. The results of the study show that the students who had opportunity to discuss their ideas experienced a conceptual change in their atomic structure concepts. This study also emphasizes the importance of history and philosophy of science perspective in science teaching. The researchers suggest that control group students who had just a traditional instruction on historical, epistemological, and philosophical aspects of atomic structure could perhaps facilitate students' conceptual understanding.

Scott, Asoko, and Driver (1991) discuss two main groups of strategies to promote conceptual change. These groups are the strategies based on cognitive conflict and the ones based on extending previous conceptions of the students. The cognitive conflict strategies "involve promoting situations where the students' existing ideas about some phenomenon are made explicit and are then directly challenged in order to create a state of cognitive conflict" (p.2). Students are required to resolve their conflictions through these strategies. In the other group strategies, students should build on their existing ideas by developing and extending these ideas to the scientific ideas. Weaver (1998) conducted research to summarize teaching strategies which promote conceptual change and found that especially laboratory or hands on activities and real life content are interesting for the students and facilitate conceptual change during students' science learning.

Using the strategies such as demonstrations or anomalies is required for the students to have dissatisfaction with their alternative conceptions (Hewson & Thorley, 1989). In order to promote conceptual change, it is important for the students to participate in discussion during the instruction. Discussion enables students to be aware of both their own ideas and others' ideas. The strategies based on conceptual change require teachers and students to be active and engaged in the activities during the instruction. Teachers should encourage students to make explanations and interpretations by using their ideas while applying these strategies.

In order to eliminate students' misconceptions, many instructional strategies based on conceptual change approach have been used and their effects on students' understanding of scientific concepts have been investigated. These tools vary as concept maps, conceptual change texts, cooperative learning strategy, computer assisted instruction, analogies, demonstration, and so on. Since demonstration is one of the effective strategies for students' learning of chemistry, conceptual change based instruction accompanied by demonstrations was used in this study.

2.3 Demonstrations

Demonstration, which is an effective method to increase students' conceptual understanding (Payne, 1932), is used in chemistry classrooms. During a demonstration activity, generally teacher carries out a demonstration about the topic and students observe this activity. Discussion environment after demonstrations provides opportunity for teacher and students to share their ideas about their observations related to demonstrations, making it easy for students to engage in discourse in classroom and to understand science concepts (Milne & Otieno, 2007; Skinner & Belmont, 1993).

Demonstrations also encourage students to be involved in discussion environment in classroom. Milne and Otieno (2007) explains that “science demonstrations have the potential provide a beginning point for experiencing science, talking about experiences, proposing questions, suggesting patterns, and testing those questions and patterns; structuring these into a ritual with a specific content focus provides another structure for emotionally intense and cognitively focused interactions that support student learning.” (p. 551). Since performing inquiry-based experiments in the laboratories require much time and many resources, demonstrations which provide students the opportunity to observe and discuss the process can be used to handle this problem. Throughout demonstration, the teacher can ensure the experiment is performed properly and the important points related to the experiment can be emphasized (McKee, Williamson, & Ruebush, 2007).

Demonstrations are used based on cognitive conflict strategy in order to encourage students to engage in conceptual change (Baddock & Bucat, 2008). The key feature of demonstrations based on cognitive conflict strategy is that students’ observation is contrary to their expectations. Since chemical principles are emphasized during a demonstration, students can learn basic definitions in chemistry and recall examples regarding these principles (Ophardt, Applebee, & Losey, 2005). According to Meyer, Schmidt, Nozawa, and Panee (2003), the qualities of an effective demonstration are a specific academic purpose, use of commonly available materials, student engagement, links to previous student learning and experience, showmanship (drawing attention, being easily seen and heard by all), and a post-demonstration discussion.

“Teacher directed demonstrations create cogent mental links between previous and new student learning. And teachers can easily adjust the emphasis of the demonstrations to maximize this linking, thus increasing the personal relevancy of new learning.” (Meyer et al., 2003, p. 432). In fact, demonstrations help teachers to have extra time in classes since they draw students’ attention to the subject. In addition, demonstrations make a contribution to creating a positive classroom environment by leading to sharing experiences and discussion. Furthermore, demonstrations help students to develop their higher order thinking skills such as analysis, characterization, evaluation, and synthesis.

Some research has investigated students' understanding of science content by using demonstrations as a tool without focusing on the structure of the demonstrations. For example, Champagne, Klopfer, and Anderson (1980) conducted research based on some strategies in which demonstrations were used. These strategies were "demonstrate, observe, explain (DOE)" strategy and "predict, observe, explain (POE)" strategy used to evaluate students' understandings of some specific science concepts. In addition, several studies were conducted to investigate the effect of demonstrations on students' attention and involvement (Beasley, 1982); developing conceptual and critical thinking (Bowen & Phelps, 1997); and writing predictions, observations, and explanations (Shepardson, Moje, & Kennard-McClelland, 1994).

Zimrot and Ashkenazi (2007) used interactive lecture demonstrations as a teaching method in their study. In this teaching method, students are asked to make prediction the result of an experiment, observe the process, and discuss it based on students' previous expectations. "The demonstrations are designed to contradict students' known misconceptions, generate cognitive conflict and dissatisfaction with the existing conception, and promote a process of conceptual change" (Zimrot & Ashkenazi, 2007, p. 197). The researchers applied a multiple choice item test to two groups. One of the groups just observed the demonstrations without predicting and discussing the outcomes whereas the other group carried out all process for interactive lecture demonstrations. The researchers found a significant difference between the groups with respect to recalling the outcome of the demonstrations in favor of the group in which there was an interaction.

Similarly, Baddock and Bucat (2008) conducted an action research to investigate the effect of a classroom chemistry demonstration by using cognitive conflict strategy. 66 eleventh grade students in Australia attended in this study. The demonstration used in this study was related to weak acids. Some presentations, including discussions before and after, were shown to the students. After the presentation, the students were asked to reply some questions regarding the demonstration by writing. The results of the study show that there is an improvement in students' understandings of the topic even if some students had difficulties in learning this subject during the instruction because of failure to attend to the activities during the demonstration.

Buncick, Betts, and Horgan (2001) present some demonstrations regarding introductory physics course. These demonstrations with their context provide an opportunity to discuss each section of the course. Buncick et al. (2001) argues that students' predicting the results and discussing the demonstrations promotes their engagement in classroom discourse. Therefore, they aimed to improve students' conceptual understanding and persistence in science majors. There were two groups in the study, conventional group and experimental group. The researchers used the demonstrations in the experimental group. They also focused on the relationship between connectivity, engagement, and inclusivity. Their demonstration approach was evaluated by class observation of students' interaction. In addition, an attitudinal survey was administered to students at the beginning and end of the course. These results were also compared to those in conventionally taught introductory physics courses. This study contributes to changes in classroom dynamics by focusing on student engagement and inclusivity. The results of the study also show that students in the class in which demonstrations were used have more positive attitudes than those in the conventional class.

Azizoglu (2004) investigated the effect of conceptual change oriented instruction accompanied by demonstrations on tenth grade students' understanding of the concepts related to gases. A hundred 10^{th} grade students from two classes enrolled in this study. One of the classes was selected as an experimental group while the other was selected as a control group. In the experimental group, conceptual change oriented instruction accompanied by demonstrations was used whereas in the other group, traditionally designed chemistry instruction was used. The aim of the demonstrations used in the experimental group was to cause conceptual conflict and dissatisfaction with the existing but incorrect conceptions in the students' minds. Students' understanding of gases was assessed through the Gases Concept Test. The results show that the experimental group students had a better understanding of gases concepts than the control group students.

Meyer et al. (2003) have explained some reasons for not doing demonstrations. Time and energy to prepare demonstrations are teachers' difficulties in doing demonstrations in their teaching. Many teachers who have not been exposed to the key features and importance of demonstrations in chemistry assume that they need expensive materials for doing demonstrations in classes. However, the researchers claim otherwise. They argue on the reasons for doing demonstrations. Demonstrations are required minimal equipment and materials and produce minimal waste. Moreover, students have the opportunity for engaging in chemistry itself because of demonstrations.

Harty and Al-Faled (1983) conducted a study to investigate the effect of demonstrations on students' conceptual understanding. There were two groups in the study. In one group, lecture-demonstration instruction was used, whereas in the other lecture-laboratory instruction was used. An achievement and an attitude survey were administered to students before and after the treatment as pre-test and post-test, respectively. The results show that attitudes of the students in both groups changed but there was no significant difference between two groups with related to students' attitudes. Although conceptual understanding of both groups increased, the lecture-laboratory group had significantly better conceptual understanding than the other group. Therefore, the use of demonstrations can be suggested when the circumstances for using laboratory activities are not available.

Thompson and Soyibo (2002) investigated the effects of lecture, teacher demonstrations, class discussion and practical work on students' attitudes toward chemistry and understanding of the subject of electrolysis. The sample of their study consisted of 138 10th grade students aged 14-16 years from two high schools in Jamaica. There were two groups in both schools: the experimental and control groups. In the experimental group, teachers used lecture, teacher demonstrations, class discussion and practical work in small groups whereas the teachers in the control groups used only the lecture method, teacher demonstrations and class discussion. The instruments were the Attitudes to Chemistry Questionnaire and Understanding of Electrolysis Test. The results show that post-test attitudes and post-test understanding of electrolysis mean scores of the experimental group students were significantly better than those of the control group students. In addition, a positive, statistically significant but weak relationship was found between the experimental group treatment and their performance on understanding test items while this relationship for control group students was not statistically significant.

McKee et al. (2007) carried out a research with a sample of six laboratory sections of students who enrolled in a first semester general chemistry course at a public southwestern university in order to compare the effects of laboratory and demonstration on students' understanding. The students in the control group performed the laboratory in the manner customary for this course whereas those in the experimental group observed the laboratory performed as a demonstration. A concept test was applied to students as both a pre-test and a post-test to assess their conceptual understanding. The results of this study showed that conceptual understanding of the students in both groups increased but no significant difference with respect to their conceptual understanding was found between two groups after treatment.

2.4 Attitude

One of the main goals of science education is to enable students to develop positive attitudes toward science. The development of scientific literacy among students requires their positive attitudes toward science (Linn, 1992). As Nieswandt (2007) puts it, "students' interests and attitudes toward science as well as their perceptions of how well they will perform in learning contexts (self-concept) may play important roles in developing a meaningful understanding of scientific concepts, an understanding that goes beyond rote memorization toward the ability to explain everyday phenomena with current scientific knowledge." (p. 908).

There are some research findings showing evidence for the relationship between students' attitudes towards school science and their achievement in science (e.g., Neathery, 1997; Osborne & Collins, 2000; Simpson & Oliver, 1990). These studies show that the students who have more positive attitudes towards science would be more successful in science classrooms. Some meta-analysis studies present consistent results with respect to this relationship. For example, in a meta-analysis research conducted by Weinburgh (1995) the correlation between students' attitudes toward science and their science achievement was found as 0.50 for male students and 0.55 for female students. Steinkamp & Maehr (1983) determined the mean correlation between attitude and achievement regarding science as 0.19 by investigating 66 studies. Willson (1983) found this mean correlation as 0.16 by investigating 43 studies. Marsh (1992) reported the correlation between science related self-concept (as subscale of attitude) and science achievement as 0.70 in the study conducted with eighth and tenth grade Australian male students. Freedman (1997) carried out a study by using a post-test only control group design and found the correlation between students' attitudes toward science and their achievement as 0.41 in the experimental group.

According to Koballa and Glynn (2007), students' science learning experiences affect their attitudes positively, increase their motivation for science learning, and as a result, lead to higher achievement in science. Indeed, they (Koballa & Glynn, 2007) point out that "approaches to positively affecting student attitudes include instruction that emphasizes active learning and the relevance of science to daily life" (p. 95). The development of students' positive attitudes toward school science is also important since it affects students' choice of science lessons in schools and their career choice in this field (Cavallo & Laubach, 2001; Glasman & Albarracin, 2006; Simpson & Oliver, 1990).

Instructional method in science classroom is one of the variables with respect to students' perceptions in science courses (Ebenezer & Zoller, 1993). Science teacher has also effect on students' attitudes toward science (Cavallo & Laubach, 2001; Myers & Fouts, 1992). Since many activities such as instructional activities, interactions among students, students' participation are guided by teachers in science classroom; science teachers play a key role in promoting positive attitudes towards science in students. Myers and Fouts (1992) found that more positive attitudes of students were related to involvement, personal support, relationships with classmates, and various teaching strategies and unusual learning activities.

Simpson and Oliver (1990) investigated the factors affecting students' attitudes towards science and their achievement in science. They found that students with low anxiety were more successful in science than students with high anxiety. Another result in this study shows that there was a positive relationship between students' achievement in science and their motivation towards science as a construct of attitudes toward science. Oliver and Simpson (1988) investigated the relationship between three attitude subscales, which are attitudes toward science, achievement motivation, and science related self-concept, and science achievement. They found that achievement motivation and science related self-concept were significant predictors of students' science achievement. These subscales explained 10% of the variance in science achievement.

Mattern and Schau (2002) carried out a study in order to determine the best fitting structural equation model of the relationships between attitudes toward science and science achievement for White middle school students. 1238 seventh and eighth grade students from eight schools in northern New Mexico participated in this study. In data collection procedure, a 5-point Likert scale was used to assess three subscales of attitude which were affect, cognitive competence, and value. Two instruments were used to assess students' science achievement which were related to general science knowledge and connected understanding of science concepts. The researchers determined the cross-effects model between attitudes and achievement as the best fitting model for all the students. However, different results were found when gender effect was considered. The no attitudes path model was the best fitting model for male students. This result implies that there was no important unique effect of previous attitudes on post-attitudes for boys and their previous achievement affected their post-attitudes. For female students, the no cross-effects model was the best fitting model. The values for the cross-paths between attitude and achievement were found as small and not statistically significant for female students. Instructional strategies which focus on high achievement in science should foster both science learning and more positive attitudes toward science.

Students also have different attitudes toward different domains of science: physics, chemistry, and biology (Osborne & Collins, 2001). There has been substantial research related to attitudes toward science. However, only some research has focused on a particular field of science such as chemistry (Hill, Pettus, & Hedin, 1990; Menis, 1983, 1989). Attitude toward chemistry refers to "a person's liking or disliking of chemistry" (Nieswandt, 2007, p. 912) or to having a "positive or negative feeling" (Koballa & Crawley, 1985, p. 223) with respect to chemistry.

Menis conducted two studies, one of them in Israel (1983) and the other one in the USA (1989), on students' attitudes toward chemistry and science. He proposes three factors under attitudes toward chemistry and science, which are attitude toward the importance of chemistry and science, attitude toward chemistry and science as a career, and attitude toward chemistry and science in school curriculum. Schibeci and Riley (1986) argue that students' attitudes toward science are affected by the activities carried out in the chemistry classes. In addition, a positive attitude toward science is also related to laboratory practices in courses (Freedman, 1997).

There is evidence supporting that students' learning experiences in chemistry classes affect their attitudes toward chemistry (Hill et al., 1990) and enrollment choices (Koballa, 1990). Lawrenz (1976) found that when chemistry students had experiences in a low-conflict learning environment, they had more positive attitudes toward science. Students' attitudes toward science have an influence in their selections of science course, their learning outcomes, and their choice of future career (Koballa, 1988; Laforgia, 1988).

Dalgety, Coll, and Jones (2003) developed an instrument, Chemistry Attitudes and Experiences Questionnaire to assess university chemistry students' attitude toward science, chemistry self-efficacy, and learning experiences. After they piloted this instrument by applying it to 129 first year science and technology students at an institution in New Zealand, they administered the modified form of the instrument to 669 science and health science students at two tertiary institutions. The results of this study show that Chemistry Attitudes and Experiences Questionnaire has a good construct validity and it can be used to understand the factors affecting tertiary students' choice of chemistry enrollment.

Similarly, Salta and Tzougraki (2004) developed another questionnaire for assessing attitudes toward chemistry of the eleventh grade students in Greece and investigated students' attitudes by using this instrument which is a 5-point Likert scale. After piloting the instrument with 70 eleventh grade students, they conducted the main study with 576 eleventh grade students from seven schools. At the end of factor analysis, four subscales of attitude toward chemistry were identified as the difficulty of chemistry course, the interest of chemistry course, the usefulness of chemistry course for students' future career, and the importance of chemistry for students' life. They reported that the correlation ranged from 0.24 to 0.41 between students' attitudes toward chemistry and their achievement in this course. The findings of this study show that students had neutral attitudes regarding both the difficulty and interest of chemistry course. The students had negative attitudes regarding the usefulness of chemistry whereas they had positive attitudes regarding the importance of chemistry course. Another result was related to gender difference in attitudes toward chemistry. Although there was no significant difference between girls and boys with respect to attitudes regarding interest, usefulness, and importance, girls had significantly less positive attitudes regarding difficulty of chemistry than boys. Furthermore, it was found a low positive correlation between students' attitudes toward chemistry and their achievement in science.

The quality of science teaching is an important factor affecting students' attitudes toward school science (Ebenezer & Zoller, 1993; Osborne, Simon, & Collins, 2003). Using laboratories in science or chemistry lessons positively affects students' attitudes toward that lesson (Adesoji & Raimi, 2004). Wong and Fraser (1996) found that there was a positive correlation between students' enjoyment of chemistry lessons and using laboratory activities in chemistry lessons. "Chemistry educators need to consider different components of the chemistry curriculum in order to improve male and female students' attitudes toward chemistry lessons" (Cheung, 2009, p. 88). Using inquiry based laboratory works may make chemistry lesson more male-friendly while using humanistic approach in designing chemistry curriculum may make it more female-friendly (Cheung, 2009). In the literature, there have been many research studies on the effect of different instructional strategies on students' attitudes (Gibson & Chase, 2002; Wong, Young, & Fraser, 1997) and the effect of attitudes on achievement. In addition, there have been studies conducted to determine the effect of gender, ethnicity, and grade level on attitude (Rani, 2000).

Nieswandt (2007) investigated the relationships over time between affective variables (interests, attitudes, and self-concept) and conceptual understanding. The sample of this study consisted of seventy three 9th grade students (their ages ranged from 15 to 16) from four classes in four secondary schools in Germany. During the study the teachers used teaching approaches which ensured students to reflect their own previous knowledge about the topics. In addition, many hands-on activities were used during the instructions. The affect questionnaires developed by the researcher were administered to the students in the middle of the first semester and then at the end of the second semester of 9^{th} grade. These affect questionnaires were situational interest, chemistry-specific self-concept, and attitudes toward chemistry. The conceptual understanding questionnaire was administered at the end of the second semester of 9^{th} grade and at the beginning of 10^{th} grade. The items in the questionnaire assessing conceptual understanding focused on two main concepts in chemistry: "changes of matter" and "structure and matter of substances". Furthermore, the contexts of these items were the tasks based on everyday problems. The structural equation modeling was used as data analysis approach. The analysis results show that attitudes toward chemistry do not have an important mediating role in the development of students' conceptual understanding. The final model found in the study shows a more mediating role of chemistry-specific self-concept causes greater conceptual understanding. Another finding suggests that situational interest has a direct effect on conceptual understanding. This result implies that situational interest is not sufficient for long-term conceptual understanding.

Another study related to the factors affecting chemistry achievement and chemistry attitudes was conducted by Demircioglu and Norman (1999). The sample of the study consisted of 205 science students with ages 16-17 from two different types of high schools in Ankara, Turkey. As attitude questionnaire, they used Chemistry Attitude Scale developed by Berberoglu (1990). The factors of this scale were determined as feelings (attitude factor 1) and lab work (attitude factor 2). The results of this study show that there is no significant effect of gender on students' chemistry achievement, feelings subscale of attitude, and laboratory subscale of attitude whereas there is a significant effect on cumulative secondary school grades. It was also reported that school type had a significant effect of on students' chemistry achievement and feelings subscale.

Many studies show results related to the effect of conceptual change based instruction on students' attitudes towards chemistry (Azizoglu, 2004; Uzuntiryaki, 1998). In some of these studies (e. g. Bozkoyun, 2004; Cam, 2009), the positive effect of conceptual change based instruction was presented whereas in some (e.g.

Azizoglu, 2004) it was reported that this instruction had no effect of on students' attitudes toward chemistry as a school subject. Therefore, in this study, the effectiveness of conceptual change instruction on students' attitudes toward chemistry as a school subject was also investigated.

2.5 Gender Effect on Conceptual Change and Attitude

Students' conceptual understanding of science concepts and their attitudes toward science or a field of science may differ based on their gender. In the literature, while there has been some research which has evidence supporting that gender difference has an effect on students' conceptual change (e.g. Cetin, Kaya, & Geban, 2009; Wang & Andre, 1991; Westbrook, 1990), the findings of some research show that gender difference does not affect conceptual understanding of the students (e.g. Baser & Geban, 2007; Cakir, Uzuntiryaki, & Geban, 2002; Ye & Wells, 1998).

Baser and Geban (2007) investigated the effect of gender on students' understanding of heat and temperature concepts. The sample of the study consisted of seventy two 7th grade students. They used conceptual change instruction based on conceptual change texts in the experimental group and traditional instruction in the control group. The results of their study show that there was no significant difference between males and females in terms of their understanding of heat and temperature concepts.

Cakir et al. (2002) conducted a study in order to examine the effect of concept mapping and conceptual change texts on 10th grade students' understanding of acids and bases concepts. A hundred ten students from 6 classes participated in the study. While experimental group was given conceptual change based instruction which includes concept mapping and conceptual change texts, control group was given a traditional instruction. The results address a significant effect of treatment but no significant effect of gender on students' understanding of acid and bases concepts.

Some research in which gender effect was found on students' understanding of concepts reports a difference in favor of males (e.g. Cetin et al., 2009) and some reports in favor of females (Bunce & Gabel, 2002). The effect of gender on students' conceptual understanding might be attributed to the differences in prior experience, interest, and knowledge (Chambers & Andre, 1997). Additionally, some research suggests that gender difference with respect to understanding and achievement in science is likely to stem from teachers' attitudes toward male and female students (Kahle & Meece, 1994; Tobin & Garnett, 1987). According to Wapner (1986), the reason of gender difference in learning is the difference in learning styles of males and females. Wapner (1986) explains that males use active reasoning patterns including cognitive structuring skills since they are field-independent learners, and females who are field-dependent learners are passive in learning context.

There has been some research in which gender effect was also investigated with respect to students' attitudes toward chemistry as a school subject. For example, Harvey and Stables (1986) report in their study conducted with secondary school students that male students had more positive attitudes toward chemistry than female students. Many studies report that male students have a more positive attitude toward science than female students (Francis & Greer, 1999; Jones, Howe, & Rua, 2000; Simpson & Oliver, 1985). However, in the study conducted by Dhindsa and Chung (1999), the findings address that females had more positive attitudes toward chemistry than male students.

Cheung (2009) carried out a study to examine the interaction effect between grade level and gender regarding students' attitudes toward chemistry lessons. The sample of the study consisted of 954 chemistry students whose grade levels ranged from secondary 4 to secondary 7 in Hong Kong. He surveyed students' attitudes through Attitude toward Chemistry Lessons Scale which consisted of four subscales: liking for chemistry theory lessons, liking for chemistry laboratory work, evaluative beliefs about school chemistry, and behavioral tendencies to learn chemistry. Two-way MANOVA results show that there was a statistically significant interaction between students' grade level and gender with respect to their attitudes toward chemistry as a school subject.

Similarly, Hofstein, Ben-Zvi, Samuel, and Tamir (1977) conducted a research related to gender differences in students' attitudes toward chemistry. They formed Chemistry Attitude Scale by adapting the Physics Attitude Scale developed by Tamir, Arzi, and Zloto (1974). The factors of this scale were study of chemistry in high school, social and economic image of chemistry, role of chemistry at the national-political level, and masculine-feminine image of chemistry. They administered his scale to three hundred 11^{th} and 12^{th} grade high school students in Israel. The results of their study indicate that female students had more positive attitude toward school chemistry than male students. Similarly, Shannon, Sleet, and Stern (1982) found in their study conducted with eight hundred thirty 11^{th} grade students in Australia that chemistry is a more enjoyable lesson for girls than boys.

In contrast, there has been some research in which gender difference in attitudes toward chemistry was in favor of male students. For example, Barnes, McInerney, and Marsh (2005) conducted a research with four hundred forty-nine 10^{th} grade students from 5 high schools in Sydney. To determine students' interest in chemistry lesson they used three items. The results show that chemistry is a more interesting lesson for male students than female students. Nonetheless, there is evidence related to no gender difference in students' attitudes toward chemistry. Salta and Tzougraki (2004) carried out a research with a sample of 576 high school students in Greece by using an attitude scale. This scale consisted of four factors which were the difficulty of chemistry course, the interest in chemistry course, the usefulness of chemistry course for students' future career, and the importance of chemistry for students' life. The findings of this study did not show any gender differences in students' attitudes regarding interest, usefulness, and importance of chemistry.

In sum, the literature review show that rate of reaction is one of the chemistry subjects in which students have some misconceptions because of abstract nature of the concepts with respect to this topic. Rate of reaction subject is also a prerequisite for understanding other chemical concepts such as chemical equilibrium. Therefore, students who have misconceptions related to rate of reaction are likely to have difficulties in understanding other concepts in chemistry. The literature supports that conceptual change based instruction is an effective method in remedying students' misconceptions in science and chemistry. Furthermore, demonstration has a key role in students’ understanding of chemical concepts. Using demonstrations in chemistry instruction also improves positive attitudes in students. Gender might affect students’ both understanding of chemical concepts and attitudes toward chemistry. Therefore, in this study, the effects of conceptual change based instruction accompanied by demonstrations on students’ understanding of rate of reaction concepts and their attitudes toward chemistry as a school subject were investigated. In addition, gender as another factor affecting students’ understanding of rate of reaction concepts and their attitudes toward chemistry was investigated.

CHAPTER III

PROBLEMS AND HYPOTHESES

In this chapter, the main problem, the sub-problems, and the hypotheses of the study are presented.

3.1 The Main Problem and Sub-Problems

3.1.1 The Main Problem

What is the effect of conceptual change based instruction accompanied by demonstrations on 11^{th} grade students' understanding of rate of reaction concepts, and their attitudes toward chemistry as a school subject compared to traditionally designed chemistry instruction?

3.1.2 The Sub-Problems

1. Is there a significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their understanding of rate of reaction concepts when science process skill is controlled as a covariate?

2. Is there a significant mean difference between post-test mean scores of males and females with respect to their understanding of rate of reaction concepts when science process skill is controlled as a covariate?

3. Is there a significant effect of interaction between gender and treatment on students' understanding of rate of reaction concepts when science process skill is controlled as a covariate?

4. Is there a significant contribution of science process skills to understanding of rate of reaction concepts?

5. Is there a significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their achievement in rate of reaction when science process skill is controlled as a covariate?

6. Is there a significant mean difference between post-test mean scores of males and females with respect to their achievement in rate of reaction when science process skill is controlled as a covariate?

7. Is there a significant effect of interaction between gender and treatment on students' achievement of rate of reaction when science process skill is controlled as a covariate?

8. Is there a significant contribution of science process skills to achievement of rate of reaction concepts?

9. Is there a significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their attitudes towards chemistry as a school subject?

10. Is there a significant mean difference between post-test mean scores of males and females with respect to their attitudes towards chemistry as a school subject?

11. Is there a significant effect of interaction between gender and treatment on students' attitudes towards chemistry as a school subject?

3.2 The Hypotheses

$H_0$1: There is no significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their understanding of rate of reaction concepts when science process skill is controlled as a covariate.

$H_0$2: There is no significant mean difference between post-test mean scores of males and females with respect to their understanding of rate of reaction concepts when science process skill is controlled as a covariate.

$H_0$3: There is no significant effect of interaction between gender and treatment on students' understanding of rate of reaction concepts when science process skill is controlled as a covariate.

$H_0$4: There is no significant contribution of science process skills to understanding of rate of reaction concepts.

$H_0$5: There is no significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their achievement in rate of reaction when science process skill is controlled as a covariate.

$H_0$6: There is no significant mean difference between post-test mean scores of males and females with respect to their achievement in rate of reaction when science process skill is controlled as a covariate.

$H_0$7: There is no significant effect of interaction between gender and treatment on students' achievement in rate of reaction when science process skill is controlled as a covariate.

$H_0$8: There is no significant contribution of science process skills to achievement in rate of reaction concepts.

$H_0$9: There is no significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their attitudes towards chemistry as a school subject.

$H_0$10: There is no significant mean difference between post-test mean scores of males and females with respect to their attitudes towards chemistry as a school subject.

$H_0$11: There is no significant effect of interaction between gender and treatment on students' attitudes towards chemistry as a school subject.

CHAPTER IV

DESIGN OF THE STUDY

This chapter presents the experimental design of the study, the population and sample of the study, the variables investigated in the study, the instruments used, the treatment in both experimental and control group, treatment fidelity and treatment verification, ethical issues, threats to internal validity, data analysis methods, and assumptions and limitations of the study.

4.1 Experimental Design

This study was conducted based on non-equivalent control group design as a part of quasi experimental design (Gay & Airasian, 2000). Table 4.1 shows the research design of the study.

Table 4.1 Research Design of the Study

Group	Pre-test	Treatment	Post-test
EG	RRCT RRAT ASTC SPST	CCBIAD	RRCT RRAT ASTC
CG	RRCT RRAT ASTC SPST	TDCI	RRCT RRAT ASTC

The meanings of the abbreviations in Table 4.1 are given in the following:
EG: Experimental Group
CG: Control Group
CCBIAD: Conceptual Change Based Instruction Accompanied by Demonstrations
TDCI: Traditionally Designed Chemistry Instruction
RRCT: Rate of Reaction Concept Test
RRAT: Rate of Reaction Achievement Test
ASTC: Attitude Scale toward Chemistry
SPST: Science Process Skill Test.

4.2 Population and Sample

The target population of the study is all eleventh grade high school students enrolled in a chemistry course in Ankara which is the capital of Turkey. The accessible population contains all eleventh grade students at public high schools in Cankaya, Ankara. The results of the study would be generalized to the accessible population of the study. The sample of the study was chosen by convenience sampling method. Firstly, a public high school among those in Cankaya was selected based on this sampling method. At the beginning of the semester, school administration had already formed the classes. Therefore, students could not be randomly assigned to the experimental and control groups. However, two groups of the same chemistry teacher was assigned; one being the experimental group and the other the control group.

The subjects of this study consisted of 69 eleventh grade students (27 males and 42 females) from two chemistry classes taught by the same teacher in a public high school in fall semester of 2008-2009 academic year. Two teaching methods were randomly assigned to the groups. The experimental group instructed by conceptual change based instruction accompanied by demonstrations consisted of 34 (15 males and 19 females) students, while the control group instructed by traditionally designed chemistry instruction consisted of 35 (12 males and 23 females) students. The ages of the students in both groups ranged from 16 to 17 years.

4.3 Variables

In this study, there are six variables to be investigated. Three of them are independent variables and three of them are dependent variables.

4.3.1 Independent Variables

The independent variables of this study are type of instruction method (conceptual change based instruction accompanied by demonstrations and traditionally designed chemistry instruction), gender (male and female), and students' science process skills measured by Science Process Skill Test. Instruction type and gender were considered as categorical variables and measured on nominal scale. Science Process Skill Test scores variable was considered as a continuous variable and measured on interval scale. Instruction type was coded as 1 for the experimental group and 2 for the control group. Gender was coded as 1 for male students and 2 for female students.

4.3.2 Dependent Variables

The dependent variables of this study are students' understanding of rate of reaction concepts measured by Rate of Reaction Concept Test, students' achievement in rate of reaction concepts measured by Rate of Reaction Achievement Test, and students' attitudes toward chemistry measured by Attitude Scale toward Chemistry. All dependent variables are continuous variables.

4.4 Instruments

Rate of Reaction Misconception Test, Rate of Reaction Concept Test, Rate of Reaction Achievement Test, Attitude Scale toward Chemistry, Science Process Skill Test, Interview Schedule, and Observation Checklist were used as instruments in this study.

4.4.1 Rate of Reaction Misconception Test

Rate of Reaction Misconception Test was developed in order to determine students' misconceptions with respect to rate of reaction subject by considering the instructional objectives of the rate of reaction unit (See Appendix A), eleventh grade chemistry textbooks, and the literature related to misconceptions about rate of reaction subject. This misconception test consists of 10 open-ended questions (See Appendix B). The students were asked to respond to each question and explain its reason. The questions in the test aimed to determine students' misconceptions in rate of reaction. For example, the first question was related to the effect of concentration on the rate of a reaction. In the question, an event was mentioned with respect to change in concentration of reactant and change in rate of a reaction. The students were asked to explain the reason of the change in the rate of that reaction.

For content validity of the test, the test was examined by a group of science education experts and some chemistry teachers. Then, it was administered to 86 eleventh and 92 twelfth grade students from three different high schools in the spring semester of 2007-2008 academic year. After evaluating the results of these tests, misconceptions that students had on the rate of reaction subject were determined, and during construction of the rate of reaction concept test, these misconceptions were taken into consideration.

4.4.2 Rate of Reaction Concept Test

This test was developed to measure students' understanding of rate of reaction concepts. The Rate of Reaction Concept Test (RRCT) was prepared in the light of the results of The Rate of Reaction Misconception Test, the instructional objectives of the rate of reaction unit, eleventh grade chemistry textbooks, the questions asked in University Entrance Exam in Turkey and the literature in relation to the misconceptions about rate of reaction subject (e.g. Bozkoyun, 2004; Cakmakci et al., 2003; Calik et al., 2010; Hackling & Garnett, 1985; Van Driel, 2002). The test contained 25 four-distracters multiple choice items (See Appendix C). For RRCT, the correct answers of the students were coded as "1", and their wrong answers were coded as “0”. Then, total scores of the students in both groups with respect to this test were computed. Since there are 25 items in RRCT, the maximum score which students can get from this test was “25”. Students’ higher scores in RRCT can be interpreted as having better understanding of rate of reaction concepts. For every item in the test, the distracters were prepared based on the students’ misconceptions about rate of reaction. The classification of these misconceptions in the concept test was given in Table 4.2.

For content validity of the test, a group of science education experts and some chemistry teachers examined the test. Some distracters and items were improved by considering the experts’ suggestions and interpretations. Before the treatment, Rate of Reaction Concept Test was administered to 195 eleventh grade students from three high schools as a pilot test during the spring semester of 2007-2008. The reliability of this test was found as 0.74. After completing the validity and reliability studies of this test through the use of pilot test, it was administered to the students in both groups before the treatment as a pre-test in order to assess their understanding of reaction rate concepts and after the treatment as a post-test in order to determine the effect of conceptual change based instruction on students’ understanding of reaction rate concepts.

Table 4.2 Misconceptions about Rate of Reaction in RRCT

Subject	**Misconceptions**	**Items**
Rate of Reaction and Collision Theory	Reaction rate is the collision rate of the molecules in a unit time.	16A
	Reaction rate is the time between the beginning and finishing of a reaction.	16B
	Reaction rate is the number of atoms colliding in a unit time.	16C, 3D
	Reaction rate is the change of reactants.	16D
	Reaction rate is the increase in concentration of reactants in a unit time.	1C, 1D
	For a chemical reaction to occur, the colliding particles should be in gas phase.	3A
	All collisions in gas phases produce a chemical reaction.	3C
	Reaction rate is the percentage of the colliding particles.	3E

Table 4.2 (continued)

Subject	Misconceptions	Items
Concentration Effect	When concentration of a substance increases, its kinetic energy increases; thus, rate of reaction increases.	20D
	When concentration increases, the activation energy decreases; thus, the number of particles exceeding activation energy increases and then reaction rate increases.	20C,21D 23A
	When concentration increases, density increases; thus temperature increases because the molecules collide faster, and reaction rate increases.	20E
	When concentration increases, surface area increases; thus, reaction rate increases.	20A
	Reaction rate is independent of reactants' concentration.	13B
	While a reaction occurs, concentration of products increases in time; thus, reaction rate increases.	13A,13C 13D
	Reactants' concentration and reaction rate is inversely proportional. While concentration of reactants decreases, reaction rate increases.	13A,13C 13D
	Decrease in concentration of one of the reactants increases the concentration of the other reactant; thus, reaction rate is constant.	23C
	When volume increases, reaction rate increases.	12B
	When concentration of reactants increases, activation energy decreases.	23B
	The increase in concentration of reactants has no effect on reaction rate.	23C
	The increase in concentration of reactants has no effect on number of effective collisions.	23D
	The increase in concentration of reactants decreases number of effective collisions.	12D
	The increase in concentration of reactants increases reaction rate constant.	12E
Temperature Effect	When temperature decreases, rate of endothermic reactions decreases but rate of exothermic reactions increases.	11-B
	Change in temperature does not affect reaction rate.	7D, 7E, 8D, 11C
	When temperature increases, rate of reaction decreases.	11D
	Increase in temperature increases reaction rates of only substances in gas phase.	11E
	When temperature increases, activation energy increases.	21B

Table 4.2 (continued)

Subject	Misconceptions	Items
Surface Area Effect	When particle size of reactant is decreased, its volume is decreased and therefore rate of reaction increases.	18B
	A substance which is in powdered form melts faster; thus, reaction rate increases.	18C
	Because substances with big particle size move slower than those with small particle size, their reaction rate decreases.	18D
	Reaction rate of substances with big particle size is faster than those with small particle size.	18E
Catalyst Effect	Catalyst is an intermediate substance which participates in a reaction as a reactant but gets out without affecting the reaction.	17A
	Catalyst is a substance which decreases forward reaction rate and backward reaction rate.	17B
	Catalyst is a substance which is formed and then consumed during a reaction.	17C, 25B 25E, 22C
	Catalyst is an external substance which decreases enthalpy change of a reaction (ΔH).	17E
	The substance which participates in a reaction and gets out as the same substance is an intermediate substance.	25B
	Catalyst increases activation energy.	12A, 6B 6C
	Catalyst does not change the number of effective collisions.	6C, 6E
	When activation energy of a reaction decreases, reaction rate decreases as well.	4A, 6A 6C, 24D
Reaction Mechanism	Rate equation of a reaction with mechanism is the form of multiplication of the concentrations of reactants in the fast step.	15A,19C 24A
	Rate equation of a reaction with mechanism is the form of multiplication of the concentrations of reactants in the total reaction.	15D, 19B
	Rate equation of a reaction with mechanism is the form of multiplication of the concentrations of products in the total reaction.	15-E
	Rate equation of a reaction with mechanism is the form of multiplication of the concentrations of products in the slow step.	15C
	Rate equation of a reaction which has a multiple mechanism is the form of multiplication of the concentrations of products in the fast step.	15E
	In a reaction with mechanism, activation energy of the slow step is smaller than that of fast step.	24
	The fast step in the reaction mechanism determines the reaction rate.	24A

4.4.3 Rate of Reaction Achievement Test

This achievement test was developed to measure students' achievement in the subject of reaction rate. Like in the development of Rate of Reaction Concept Test, while constructing this test, the instructional objectives of the unit of reaction rate, eleventh grade chemistry textbooks, and the questions in university entrance exam were taken into consideration. The Rate of Reaction Achievement Test (RRAT) consisted of 15 four-distracters multiple choice items (See Appendix D). The test included both quantitative test items and qualitative test items. For RRAT, the correct answers of the students were coded as "1", and their wrong answers were coded as "0". Then total scores of the students in both groups with respect to this test were computed. Since there are 15 items in RRAT, the maximum score which students can get from this test is "15". Students' higher scores in RRAT can be interpreted as having better solving problems related to rate of reaction subject.

For content validity of the test, some science education experts and chemistry teachers examined the items in the test. After necessary corrections were made by considering the comments and suggestions of both some experts in science education and some chemistry teachers, the test was applied as a pilot test to the same group of students who were also in pilot study of Rate of Reaction Concept Test. The reliability of this test was found as 0.70. After completing the validity and reliability studies of this test, it was administered to the students in both groups before the treatment as a pre-test in order to assess their achievement in rate of reaction concepts and after the treatment as a post-test in order to determine the effect of conceptual change based instruction on students' achievement on rate of reaction concepts.

4.4.4 Attitude Scale toward Chemistry

This test was used to measure students' attitudes toward chemistry as a school subject. It was developed by Geban, Ertepinar, Yilmaz, Altin, and Şahbaz (1994). The test included 15 items in 5-point likert-type scale (See Appendix E). The points are "fully agree", "agree", "undecided", "disagree", "fully disagree". The reliability of the test was found to be 0.83. This test was administered to the students in both experimental and control group before the treatment as a pre-test in order to assess their attitudes toward chemistry and after the treatment as a post-test in order to determine the effect of conceptual change based instruction on students' attitudes toward chemistry as a school subject.

In Attitude Scale toward Chemistry (ASTC), there were both positive and negative items. In this study, firstly, the data of negative items were recoded from "1" to "5", "2" to "4", "4" to "2", and "5" to "1". Then a total score of each student in both groups was calculated. The maximum score that students can get from this scale is 75 because this scale included 15 items and for every item the highest point was 5. Higher scores in ASTC mean more positive attitudes toward chemistry.

4.4.5 Science Process Skill Test

This test was used to measure students' intellectual abilities related to identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations, and graphing and interpreting data. The test originally developed by Okey, Wise, and Burns (1982) was translated and adapted into Turkish by Geban, Askar, and Ozkan (1992). This test consisted of 36 four-alternative multiple choice items (See Appendix F). Science Process Skill Test (SPST) was given to the students in both experimental and control group before the treatment. The reliability of this test was found to be 0.85.

For SPST, the correct answers of the students were coded as "1", and their wrong answers were coded as "0". Then, total scores of the students in both groups for this test were computed. Since there are 36 items in SPST, the maximum score that students can get from this test is "36". Students' higher scores in SPST mean their higher intellectual abilities related to identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations, and graphing and interpreting data.

4.4.6 Interview Schedule

This interview schedule was prepared by the researcher in order to get more detailed information related to students' misconceptions about rate of reaction subject. There were a total of 7 interview questions. These interview questions were formed by considering students' misconceptions about rate of reaction. The questions in this interview schedule were related to definition of rate of a given reaction equation, the factors affecting reaction rate such as temperature, volume, catalyst, and concentration. The detailed information about the questions was given in the results chapter. After the treatment, six students from the experimental group and six students from the control group were interviewed based on this interview scale. Each interview took about 20 minutes.

4.4.7 Observation Checklist

The observation checklist was prepared to observe the appropriateness of the treatment in both experimental and control group. The checklist consists of 15 items in 3-point likert-type scale. The points are yes, partially, and no (See Appendix G). Whether the instructions are applied properly or not in both experimental and control group was followed. Furthermore, students' participation in classroom discourse during the treatment, their interaction with both the teacher and their peers in the classroom were observed. All sessions during the treatment were observed by the researcher without any interruption.

4.5 Treatment

This study was conducted over a four-week period in the Fall Semester of 2008-2009 academic year. Two classes of the same chemistry teacher participated in this study. One of the classes was assigned as experimental group and the other one was assigned as control group randomly. While conceptual change based instruction accompanied by demonstrations was applied in the experimental group, traditionally designed chemistry instruction was applied in the control group. Both groups were instructed three 45-minute sessions per week. The same chemistry teacher instructed the students in both classes. Before the study, the teacher was trained about conceptual change based instruction. The researcher prepared a lesson plan on conceptual change based instruction for each topic. The researcher explained the lesson plans and the demonstrations to be used to the teacher. While explaining the lesson plans, the researcher focused on what she should do during chemistry instructions in both groups. In addition, the researcher informed the teacher about students' possible misconceptions about rate of reaction subject.

During the treatment, rate of reaction topics were covered as part of the regular classroom curriculum in the chemistry course in both experimental and control group. The topics covered in the classes were rate of reaction and its measurement, collision theory, activation energy, factors affecting rate of reaction (concentration, temperature, catalyst, surface area, reactant type), and reaction mechanism. The students in both groups used the same chemistry textbook. The teacher also gave the same homework to the students in both groups and solved the same quantitative questions in both groups.

At the beginning of the treatment, the students in both groups were administered Rate of Reaction Concept Test as pre-tests, in order to assess students' understanding of rate of reaction concepts, Rate of Reaction Achievement Test in order to assess students' achievement in rate of reaction, and Attitude Scale toward Chemistry in order to assess students' attitudes toward chemistry as a school subject. In addition, SPST was administered to the students in both groups before the treatment in order to find whether there is a significant difference between groups in terms of their science process skills.

In the experimental group, conceptual change based instruction accompanied by demonstrations (CCBIAD) was used during class hours. This type of instruction was designed to address students' misconceptions about rate of reaction concepts and to eliminate them by considering four conditions for conceptual change (Posner et. al, 1982), which were dissatisfaction, intelligibility, plausibility, and fruitfulness. That is to say, the conceptual change model developed by Posner et al. (1982) was followed in the treatment.

The teacher started the lesson by asking some questions related to the topic to the students to activate their prior knowledge and misconceptions related to the rate of reaction subject. Students had difficulties in justifying their answers to teacher's questions because of their existing knowledge on this subject. When they realized that their existing conceptions were insufficient in explaining the phenomena, they became dissatisfied with them. For instance, while the effect of temperature on rate of reaction was instructed, the teacher asked the students "what will happen, if we increase the temperature of the environment in which a chemical reaction is occurring?" Students gave different answers to this question. Some of their answers were "the activation energy of the reaction will increase, thus, rate of that reaction will decrease" and "because particles will move faster, the possibility of collision among particles and the occurrence of a reaction will decrease". Then, in order to enhance students' dissatisfaction with their own conceptions, the teacher asked more questions addressing the relationship between activation energy and rate of reaction, and the relationship between temperature and kinetic energy of the reacting particles. That is to say, these kinds of questions were asked to make students aware of their misconceptions and dissatisfied with their existing conceptions (dissatisfaction).

Then, the concepts were explained through the use of a demonstration related to the concept. For instance, in order to explain the relationship between temperature and rate of a reaction, the teacher performed the demonstration named as the effect of temperature on reaction rate. In this demonstration, the reaction between baking soda ($NaHCO_3$, sodium hydrogen carbonate) and vinegar (CH_3COOH, acetic acid), was shown to the students. This reaction produces carbon dioxide gas. Therefore, the rate of this reaction was observed by checking the amount of carbon dioxide gas produced in a determined time interval. The teacher performed this demonstration at three different temperatures: 0 ^{0}C, 25 ^{0}C, and 75 ^{0}C. The rate of the reaction between $NaHCO_3$ and CH_3COOH increased when temperature was increased. For every demonstration, a discussion session was carried out with the students at the end of the demonstration. The aim of these discussions was to encourage students to establish a link between new concepts and their observations on demonstrations. Thus, since the students observe sample events related to the concepts during their scientific explanation supplied by the teacher, the purpose was to make these concepts more intelligible for the students (intelligibility).

After that, new examples, especially examples from daily life, related to this topic were given to the students to enhance their understanding of the rate of reaction concepts thoroughly. For instance, after explaining the effect of increase in temperature on rate of a reaction, the teacher mentioned that we keep some of our foods in the fridge and asked its reason to the students. Thus, since the students were encouraged to use new concepts in solving problems, it was aimed that these concepts were more plausible to the students (plausibility).

Finally, the students were asked to use the new concept in explaining a new situation. For this aim, the teacher asked some questions related to the application of new concepts in the classroom or gave homework to the students. Thus, since new concepts helped students to explain unfamiliar phenomena and leads to new insights, these concepts were aimed to be more fruitful to the students (fruitfulness).

Totally six demonstrations related to the rate of reaction concepts were prepared by using some chemistry books such as the one written by Herr and Cunningham (1999) and all demonstrations were applied in the same phase (intelligibility) of conceptual change during the instruction in the experimental group. The names of the demonstrations used in the study are the following:

1. The effect of concentration on reaction rate,
2. The effect of temperature on reaction rate,
3. Iodine clock reaction,
4. Catalysts, reaction rates, and activation energy,
5. The effect of surface area on reaction rate,
6. The effect of reactant type on reaction rate.

The first demonstration, the effect of concentration on reaction rate, was performed to show students how change in concentration of a reactant affects the rate of a reaction. With this demonstration, it was aimed to overcome students' misconceptions on the relationship between concentration change and rate of reaction. For this, the reaction which occurs between baking soda ($NaHCO_3$, sodium hydrogen) and vinegar (CH_3COOH, acetic acid) was used. This is a neutralization reaction producing carbon dioxide. Therefore, the rate of this reaction can be observed through the amount of carbon dioxide gas. Through this demonstration, the students were shown the rate of a reaction increases when the concentration of a reactant increases and vice versa (See Appendix I).

The second demonstration, the effect of temperature on reaction rate, was designed in order to show students how change in temperature affects rate of a reaction by addressing their misconceptions on this subject. As in the first demonstration, the reaction which occurs between baking soda ($NaHCO_3$, sodium hydrogen) and vinegar (CH_3COOH, acetic acid) and produces carbon dioxide was used at different temperatures. Here, the rate of this reaction was also observed by checking the amount of carbon dioxide gas produced. In this activity, the aim was to make students realize that increase in temperature would increase the rate of reaction and vice versa (See Appendix J).

The third demonstration, iodine clock reaction, was also designed to show students the effect of temperature on the rate of the starch-iodine clock reaction that occurs between potassium iodate (KIO_3) and sodium metabisulfite ($Na_2S_2O_5$). Since change in temperature affects the time required for a sudden color change (from colorless to blue-black color) in this reaction, it is quite attractive for students to understand the temperature effect on reaction rate. The time intervals for color change to occur were observed at different temperatures. Students were shown that color change in this reaction occurred in a long time at low temperature when compared to the time at high temperature (See Appendix K).

The fourth demonstration, catalysts, reaction rates, and activation energy, with which aimed to show students how catalyst affects the rate of a reaction. For this, the reaction which occurs between hydrogen peroxide (H_2O_2) and manganese dioxide (MnO_2), which is catalyst for this reaction, and produces oxygen was performed. Thus, the rates of reaction were observed and compared when the catalyst was added and was not added to the reaction. This demonstration is also effective for students to understand the collision theory and activation energy. The students who have misconceptions on the effect of catalyst on reaction rate could realize that the rate of a reaction increases when a catalyst for that reaction is added to the reaction (See Appendix L).

The fifth demonstration, the effect of surface area on reaction rate, was performed with the aim of showing students the effect of surface area on the rate of a reaction. In this demonstration, the reaction which occurs between solid zinc (Zn) and hydrochloric acid (HCl), and produces hydrogen gas (H_2) was carried out. The surface area of zinc was varied by using solid zinc pieces and dust zinc. The effect of changing surface area on reaction rate was determined by observing the amount of the gas (H_2) produced during the reaction. The students were shown that the rate of reaction increased when the surface area of the solid zinc was increased by addressing the amount of gas produced (See Appendix M).

The sixth demonstration, the effect of reactant type on reaction rate, was carried out in order to emphasize that reactant type used in a reaction affects the rate of the reaction. This effect was shown through the reaction between hydrochloric acid (HCl) and aluminum (Al) and the reaction between hydrochloric acid (HCl) and magnesium (Mg). Both reactions produce hydrogen gas (H_2); therefore, rate of these reactions could be compared by checking the amount of gas produced (See Appendix N).

While using all these activities in the experimental group, traditionally designed chemistry instruction was applied in the control group. During the instruction, the teacher used lecturing and discussion methods in the classroom. The sessions in this group were mainly based on teacher's presentation of the topics. The lessons began with the teacher introducing the topic to the class. When the students did not understand the subject, they asked questions and the teacher made extra explanations by giving daily life examples. However, the teacher taught the subjects without considering students' misconceptions and previous knowledge. After teacher's solving an exercise related to that topic, the students were asked to solve some exercises from either their textbook or other supplementary books. The teacher asked mostly quantitative questions to the students. During these practices, the students sometimes discussed the key points related to the topic. At the end of the lesson, the teacher made a summary of the topic to clear it up for the students. Finally, some homework was assigned to them.

In addition, the teacher distributed worksheets to the students in both groups. These worksheets prepared by the researcher and the teacher covered questions related to each sub topic. Some questions in the worksheet were solved in the classroom and the others were assigned as homework to the students. Each week, the teacher collected students' work, examined them, and gave feedback to the students in the following week. After treatment, all students were administered Rate of Reaction Concept Test, Rate of Reaction Achievement Test, and Attitude Scale toward Chemistry as post-tests in order to measure the effect of treatment on students' understanding of rate of reaction concepts, their achievement in rate of reaction concepts, and their attitudes toward chemistry, respectively.

4.6 Treatment Fidelity and Treatment Verification

To ensure treatment fidelity, firstly a criterion list explaining what should be done and what should not be done during instruction in the experimental and control group was prepared. For example, in the experimental group, conceptual change based instruction accompanied by demonstrations was used. Therefore, each step of this instruction and how these steps would be performed were determined in this criterion list. This procedure was achieved for not only the conceptual change based instruction accompanied by demonstrations group but also the traditional designed chemistry instruction group. Then, detailed lesson plans were prepared by considering this criterion list and the instructional objectives with respect to the rate of reaction subject. After that, three experts in general chemistry and chemistry education, and two chemistry teachers examined these lesson plans, the demonstrations to be performed, and the instruments to be used in the study by considering the purpose of the study. Based on the feedback from the experts, some revisions in these materials were carried out. Finally, the teacher who would apply these instructions in both groups was trained in order to make conceptual change method clear to her, and to implement the lesson plans prepared by the researcher.

For treatment verification of the study, the researcher prepared an observation checklist including the steps in the instruction to be used in the experimental and control groups in order to control whether treatment in both groups was performed properly during classroom sessions as planned before. This observation checklist consisted of 15 items in 3-point likert-type scale (yes, partially, and no). The experts defined above examined the steps in the checklist by considering the purpose of the study. The researcher observed the groups by using this observation checklist during the treatment. Furthermore, the researcher interviewed with the teacher and some students about appropriateness of the implementation in terms of purpose of the study. According to the rating results on the checklist and the interviews conducted with the teacher and the students, the researcher concluded that the treatment in both groups was applied as planned before the instruction.

4.7 Ethical Issues

This study's appropriateness in terms of ethical issues was examined and approved by a committee on ethical issues including five professors at the faculty of education before conducting the research. The study did not give any harm to the students participated in the study. The teacher performed the demonstrations during the instruction in the experimental group and the chemicals used in these demonstrations were not harmful or dangerous for both teacher and the students. In addition, confidentially of research data was ensured by assigning number to each test of the students. The students were also informed about the fact that their names would be removed from the tests and that all the data collected from them would be held in confidence. Furthermore, a consent form about usage of visuals (i.e. photos took during performing demonstrations) in the dissertation was taken from the teacher.

4.8 Threats to Internal Validity

Internal validity refers to that the differences on the dependent variable were occurred just because of independent variable in the study, not other irrelevant variables (Fraenkel & Wallen, 2006). Threats to internal validity are subject characteristics, loss of subjects (mortality), location, maturation, instrumentation, testing, history, attitude of subjects, regression, and implementation.

Subject characteristics threat occurs when the participants in the study differ in terms of their age, gender, socioeconomic status, existing knowledge, and science process skills, etc. The ages of the students whose grade level was 11^{th} grade varied from 16 to17. In this study, students' previous knowledge about the rate of reaction subject was checked by using Rate of Reaction Concept Test, Rate of Reaction Achievement Test, and their science process skills were checked by using Science Process Skill Test. In the analyses of these pre-tests, no significant difference was found between the groups. In addition, the teacher mentioned that students' socioeconomic status were close to each other.

Mortality threat in the study was also under control since there was no any missing data from all pre- and post-tests. Location is another threat which results from the effect of particular location on the results of the study. However, this threat was controlled because the study was conducted in the students' regular classrooms at the school and during regular school hours. Through this controlling way, the maturation threat which is the effect of time interval on the dependent variables was also handled.

As an instrumentation threat, instrument decay which results from the nature of the instrument (e.g. scoring procedure) was controlled because the instruments included either multiple choice items (RRCT, RRAT, SPST) or likert-type items (ASTC). Additionally, since the same teacher gathered all data from both experimental and control groups, data collectors' characteristics threat as the other instrumentation threat was controlled as well. In order to control data collector bias as another instrumentation threat, the teacher was trained for applying standard procedures during data collection.

Rate of Reaction Concept Test, Rate of Reaction Achievement Test, and Attitude Scale toward Chemistry were administered to the students in both groups before and after the treatment. Since the pre-tests and post-tests were the same tests, the post-test results might be affected from this situation. This situation which is defined as testing threat was thought to be minimized because the time interval between administering these two tests was six weeks.

The researcher observed all classroom sessions during the treatment. Any extraordinary or unplanned event did not happened during the classroom instructions and administering the instruments. Because history threat, which is any event affecting students’ performance, did not occur in the classroom, this threat was controlled.

While the students in the experimental group received conceptual change based instruction accompanied by demonstrations, the students in the control group received traditional designed chemistry instruction. For this reason, there was a possibility for the students in the control group to become demoralized and to be unsuccessful in tests and for those in the experimental group to perform successfully after the treatment. It is another threat to internal validity, named attitude of students toward the study. This threat was controlled by telling the students in the experimental group that the treatment performed in the class was just a regular part of the instruction and by telling the students in the control group that the demonstrations conducted in the experimental group would be performed later in their classes.

Regression threat did not occur in the study because the students were not selected based on their high or low performance in the pre-tests. Personal bias of the person who administered the study in favor of one group might cause unintended or unnecessary activities or parts in that group. The threat named implementation was controlled in this study because the teacher, not the researcher, instructed both groups during the study. Furthermore, the teacher was trained about the methods to be used in the experimental and control groups and the researcher also conducted treatment verification in order to ensure the controlling of this threat.

4.9 Data Analysis

4.9.1 Descriptive Statistics Analysis

Mean, standard deviation, kurtosis, skewness, minimum and maximum values were calculated and histograms were performed as descriptive statistics by using the Statistical Program for Social Science (SPSS) to analyze the data in the study. These descriptive statistical analyses were performed for Rate of Reaction Concept pre- and post-test scores, Rate of Reaction Achievement pre- and post-test scores, Attitude toward Chemistry pre- and post-test scores, and Science Process Skill Test scores of the students in both groups.

4.9.2 Inferential Statistics Analysis

In order to check the equality of the groups in terms of the scores of Rate of Reaction Concept Test, Rate of Reaction Achievement Test, Attitude Scale toward Chemistry, and Science Process Skill Test before the treatment, independent sample t-tests were used.

To analyze the effect of treatment (CCBIAD versus TDCI) and gender (male versus female) on students' understanding and achievement related to the rate of reaction concepts, Analysis of Covariance (ANCOVA) and Analysis of Variance (ANOVA) were used. In ANCOVA, the variable of students' science process skills was the covariate. Two-way ANOVA was used to find out the effect of treatment and gender on students' attitudes towards chemistry as a school subject

4.10 Assumptions and Limitations

4.10.1 Assumptions

1. The teacher followed the researcher's instructions related to treatment and she was not biased while performing the instruction in both groups.

2. There was no interaction between the students in the experimental group and the students in the control group during the study.

3. RRCT, RRAT, ASTC, and SPST were administered to the students in both groups under standard conditions.

4. All students completed the tests given to them sincerely.

5. The interviews with students were performed under standard conditions.

6. The students who were interviewed answered the questions during interview sincerely.

4.10.2 Limitations

1. This study was limited to sixty nine 11^{th} grade students from a public high school in Ankara during the fall semester of 2008-2009 academic year.

2. This study is limited to the rate of reaction subject.

3. The participants of the study could not be randomly assigned to the groups.

CHAPTER V

RESULTS AND CONCLUSIONS

This chapter presents the results of descriptive statistics analyses; the results of inferential statistics analyses; the results of student interviews; the results of classroom observations; and the conclusions arrived at in line with the results of all data analyses.

5.1 Descriptive Statistics Analyses

Descriptive statistics related to students' rate of reaction concept pre- and post-test scores, rate of reaction achievement pre- and post-test scores, attitude toward chemistry pre- and post-test scores, and science process skill test scores in the experimental and control groups were determined. These statistics such as minimum (min), maximum (max), mean, standard deviation (SD), skewness, and kurtosis are presented in Table 5.1.

As seen in Table 5.1, the experimental group students' pre-Rate of Reaction Concept Test (pre-RRCT) scores ranged from 3 to 14 with a mean value of 7.21 while the control group students' pre-RRCT scores ranged from 3 to 12 with a mean value of 6.86. The mean value of the experimental group students' post-Rate of Reaction Concept Test (post-RRCT) scores ranged from 13 to 24 was 18.85. However, the mean value of the control group students' post-RRCT scores ranged from 3 to 23 was 13.97. Thus, the mean value increase with respect to RRCT (18.85-7.21=11.64) in the experimental group was higher than the mean value increase (13.97-6.86=7.11) in the control group.

Table 5.1 Descriptive Statistics Related to Rate of Reaction Concept Test (RRCT), Rate of Reaction Achievement Test (RRAT), Attitude Scale toward Chemistry (ASTC), and Science Process Skills Test (SPST)

Descriptive Statistics								
Group	Test	N	Min	Max	Mean	SD	Skewness	Kurtosis
EG	Pre-RRCT	34	3,00	14,00	7,21	2,29	,789	1,101
	Post-RRCT	34	13,00	24,00	18,85	2,39	-,198	-,069
	Pre-RRAT	34	0,00	6,00	3,15	1,42	-,479	-,054
	Post-RRAT	34	7,00	15,00	11,44	1,94	-,354	-,390
	Pre-ASTC	34	33,00	75,00	59,03	9,56	-,638	,093
	Post-ASTC	34	50,00	75,00	63,29	6,93	-,089	-,952
	SPST	34	12,00	28,00	20,50	4,13	-,183	-,757
CG	Pre-RRCT	35	3,00	12,00	6,86	2,28	,298	-,350
	Post-RRCT	35	3,00	23,00	13,97	4,71	-,396	,052
	Pre-RRAT	35	0,00	6,00	2,63	1,50	,797	,076
	Post-RRAT	35	3,00	14,00	9,60	2,79	-,372	-,493
	Pre-ASTC	35	38,00	75,00	57,14	8,62	,176	,289
	Post-ASTC	35	31,00	75,00	56,46	11,28	-,395	,015
	SPST	35	10,00	27,00	19,49	4,06	-,254	-,428

The experimental group students' pre-Rate of Reaction Achievement Test (pre-RRAT) scores ranged from 0 to 6 with a mean value of 3.15 while the control group students' pre-RRAT scores ranged from 0 to 6 with a mean value of 2.63. The mean value of the experimental group students' post-Rate of Reaction Concept Test (post-RRAT) scores ranged from 7 to 15 was 11.44. However, the mean value of the control group students' post-RRAT scores ranged from 3 to 14 was 9.60. Similar with RRCT results, the mean value increase with respect to RRAT (11.44-3.15=8.29) in the experimental group was higher than the mean value increase (9.60-2.63=6.97) in the control group.

The experimental group students' pre-Attitude Scale toward Chemistry (pre-ASTC) scores ranged from 33 to 75 with a mean value of 59.03 and the control group students' pre-ASTC scores ranged from 38 to 75 with a mean value of 57.14. With respect to post-Attitude Scale toward Chemistry (post-ASTC), the scores of the students in the experimental group ranged from 50 to 75 with a mean value of 63.29 and those in the control group ranged from 31 to 75 with a mean value of 56.46. These descriptive statistics of ASTC scores indicated that while there was an increase in the mean value of scores of the experimental group students (63.29-59.03=4.26), there was a decrease in the mean value of the scores of the control group students (56.46-57.14= -.68)

The experimental group students' SPST scores ranged from 12 to 28 and the control group students' SPST scores ranged from 10 to 27. The mean value of SPST scores of the students in the experimental group was 20.5 and the mean of this test of those in the control group was 19.49. Although the mean value of the experimental group students was higher than the control group students, this difference was not statistically important as seen from the t-test analysis result presented in the inferential statistics analyses part.

Besides minimum, maximum, and mean values, skewness, and kurtosis values were presented in Table 5.1. The skewness and kurtosis values near to "0" indicate a normal distribution of the test scores. Therefore, the skewness and kurtosis values in Table 5.1 show that the test scores were normally distributed. This result can also be checked from Figure 5.1, Figure 5.2, and Figure 5.3, which are the histograms of post-RRCT, post-RRAT, and post-ASTC scores.

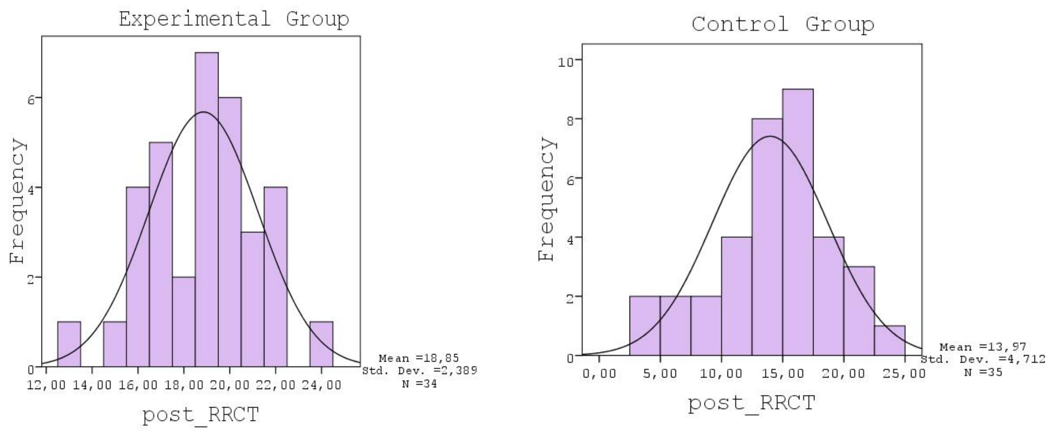

Figure 5.1 Histograms of Post-Rate of Reaction Concept Test Scores in the Experimental and Control Group

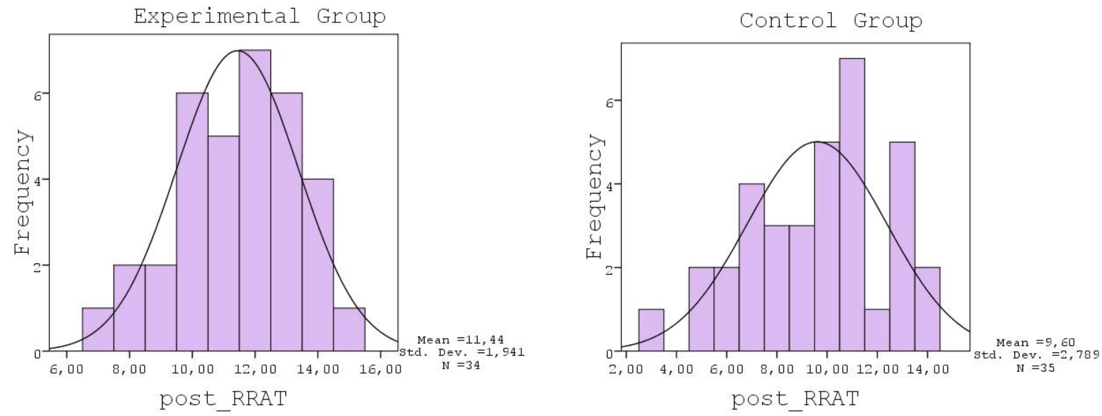

Figure 5.2 Histograms of Post-Rate of Reaction Achievement Test Scores in the Experimental and Control Group

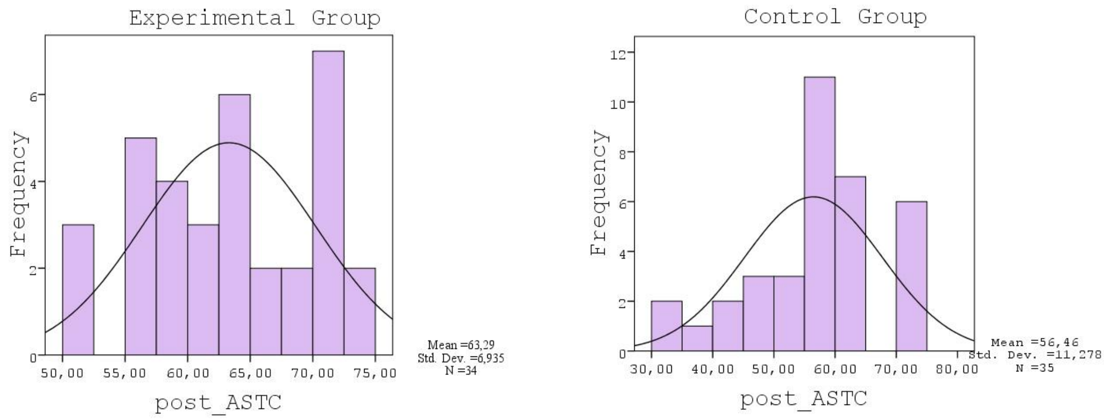

Figure 5.3 Histograms of Post-Attitude Scale towards Chemistry Scores in the Experimental and Control Group

5.2 Inferential Statistics Analyses

The analyses results of 11 null hypotheses stated in Chapter III are presented in this section. The hypotheses were tested by using Analysis of Covariance (ANCOVA) and two-way analysis of variance (ANOVA) at a significance level of .05. These statistical analyses were carried out by using the Statistical Package for Social Sciences for Personal Computers (SPSS/PC).

Before these analyses, independent samples t-test analyses were performed in order to check whether there was a significant mean difference between the experimental and the control group in terms of students' understanding of rate of reaction concepts measured by pre-RRCT, their achievement in rate of reaction concepts measured by pre-RRAT, their attitudes towards chemistry measured by pre-ASTC, and their science process skills measured by SPST.

The results of independent t-test analyses show that there was no significant mean difference between the scores of the students in the experimental group and those in the control group regarding students' understanding of rate of reaction concepts (t (69) = .634, p = .921), their achievement in rate of reaction concepts (t (69) = 1.477, p = .891), their attitudes towards chemistry (t (69) = .861, p = .210), and their science process skills (t (69) = 1.029, p = .713).

5.2.1 Null Hypothesis 1

This hypothesis stating that there is no significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their understanding of rate of reaction concepts when science process skill is controlled as a covariate was tested by using Analysis of Covariance (ANCOVA).

Before conducting ANCOVA, the assumptions of ANCOVA were tested. The assumptions of ANCOVA are the following:

i. Independence of observations within and between groups,
ii. Normality of sampling distribution,
iii. Equal variances,
iv. No custom interaction between independent variable and covariate,
v. Significant correlation between dependent variable and covariate.

For the first assumption of ANCOVA, all tests were administered to the students in the standard conditions. In addition, it was assumed that there was no interaction within and between groups during the administration of the tests. For the second assumption of ANCOVA, the skewness and kurtosis values of post-RRCT scores of the students in both groups presented in Table 5.1 show that RRCT scores are normally distributed. For the third assumption of ANCOVA, Levene's Test of Equality result ($F (1, 67 = .02, p<.05$) show that the variances of the post-RRCT scores of the students in both groups were not equal (Table 5.2). Even though this assumption was not met, the analysis was performed.

Table 5.2 Levene's Test of Equality of Error Variances for Post-RRCT

	F	df1	df2	Sig.
Post-RRCT	9.940	1	67	0.02

For the fourth assumption of ANCOVA that there should not be a custom interaction between independent variable and covariate, the results in Table 5.3 show that there is no custom interaction between treatment and students' science process skill test scores ($F (1, 1) = 0.296, p>.05$).

Table 5.3 Test of Between-Subjects Effects for Post-RRCT (Treatment-SPST)

Source	df	SS	MS	F	p
Treatment	1	34.506	34.506	2.461	0.122
SPST	1	27.921	27.921	1.992	0.163
Treatment & SPST	1	4.149	4.149	0.296	0.588

For the fifth assumption, the correlation between students' rate of reaction concept test scores and science process skill test scores was calculated. The result given in Table 5.4 points out that there was a significant correlation between rate of reaction concept test scores and science process skill test scores of the students ($r = .211, p<.05$).

Table 5.4 Correlation between Post-RRCT Scores and SPST Scores

		Post-RRCT	SPST
Post-RRCT	Pearson Correlation	1	0.211*
	Sig.		0.041
	N	69	69
SPST	Pearson Correlation	0.211**	1
	Sig.	0.041	
	N	69	69

*significant at .05

After testing all assumptions, ANCOVA was conducted. The results of the analysis were summarized in Table 5.5. These results show that there was a significant mean difference between post-test mean scores of the students taught with conceptual change based instruction and the students taught with traditionally designed chemistry instruction with respect to their understanding of rate of reaction concepts when science process skill is controlled as a covariate ($F(1, 64) = 27.815$, $p < .05$). The conceptual change based instruction accompanied by demonstrations (CCBIAD) group scored significantly higher than traditionally designed chemistry instruction (TDCI) group ($\bar{X}$ (CCBIAD) = 18.85, $\bar{X}$ (TDCI) = 13.97).

Table 5.5 ANCOVA Summary of Post-RRCT

Source	df	SS	MS	F	p
Covariate (SPST)	1	27.731	27.731	1.970	0.165
Gender	1	5.141	5.141	0.365	0.548
Treatment	1	391.549	391.549	27.815	0.000
Gender & Treatment	1	9.689	9.689	0.688	0.410
Error	64	900.929	14.077		

The proportions of correct responses to the questions in the post-RRCT for both groups are presented in Figure 5.4. As seen in this figure, there was a significant difference in the proportion of correct responses to the questions numbered with 7, 12, 14, 16, 17, 20, 22, and 24 in the post-RRCT between the experimental and control group.

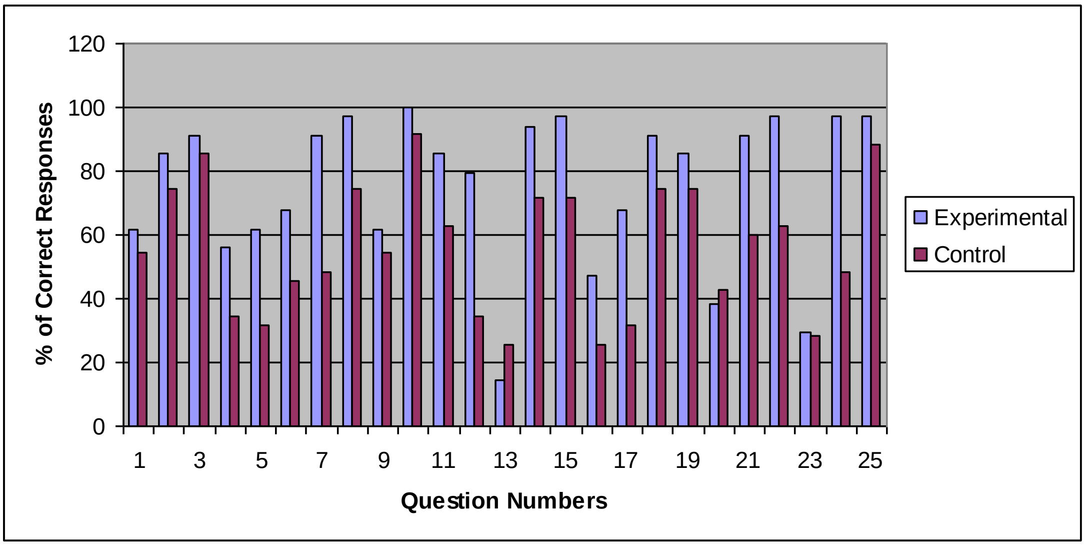

Figure 5.4 Comparison between Post-RRCT Scores of the Experimental and Control Group

Table 5.6 Percentage of Students' Responses to Question 7

Question 7: Which one is not dependent on temperature during a reaction?	Percentage of Students' Responses (%)	
	Experimental Group	Control Group
Alternative A* Activation energy	91.2	48.6
Alternative B Rate of molecules	0	2.9
Alternative C Kinetic energy of molecules	0	2.9
Alternative D Collision number of molecules	0	0
Alternative E Number of molecules that have activation energy	8.8	45.7

*Correct Alternative

In the 7th question, the students were asked to select the property which was not dependent on temperature during a reaction. Before the treatment, most of students in both experimental group (61.8 %) and control group (60 %) selected the distracter stating number of molecules that have activation energy. After treatment, while 91.2

% of the students in the experimental group correctly answered this question by selecting activation energy as independent of temperature during a reaction, 48.6 % of the students in the control group correctly answered this question. In Table 5.6, the alternatives including both distracters and correct one of this question, and also the percentages of the students' responses to this question in both groups were shown.

In the 12th question, the students were asked to select the alternative stating the factor and its effect on reaction rate during a reaction. Before treatment, the most selected alternative for this question was that catalyst increased activation energy of the reaction. For example, 50 % of the students in the experimental group and 34.3 % of the students in the control group selected the alternative stating this misconception before the treatment. However, the percentage of the students in the experimental group who had this misconception was 2.9 and the percentage of those in the control group who had the same misconception was 25.7 after the treatment.

In the 14th question, a reaction and its rate law were given and the students were asked to select the wrong statement among the alternatives related to this reaction. Before treatment, the most selected alternative was that the reaction occurs in more than one step. For instance, in the experimental group 32.4 % of the students and in the control group 22.9 % of the students selected this alternative before the treatment. In addition, the percentage of the students in the experimental group who selected the correct alternative was 23.5 and the percentage of the students in the control group who selected the correct one was 31.4. After the treatment, 94.1 % of the students in the experimental group answered this question correctly although 71.4 % of the students in the control group answered this question correctly. The percentage of the most selected distracter for this question after the treatment was 5.9 in the experimental group and 20.0 in the control group.

In the 16th question, the students were asked to choose the correct statement with respect to rate of reaction. Before the treatment, 11.8 % of the students in the experimental group and 14.2 % of the students in the control group selected the correct alternative. However, after the treatment these percentages were 47.1 in the experimental group and 25.7 in the control group. Before the treatment, the most selected alternative stating the misconception which is that reaction rate is the collision rate of molecules in a unit time was 47.1 in the experimental group and 34.3 in the control group. However, after the treatment, this alternative was selected by 23.5 % of the students in the experimental group and 34.3 % of the students in the control group. The alternatives including both distracters and correct one of this question, and also the percentages of the students' responses to this question in both groups are shown in Table 5.7.

Table 5.7 Percentage of Students' Responses to Question 16

Question 16: Which one is correct with respect to rate of reaction?	Percentage of Students' Responses (%)	
	Experimental Group	Control Group
Alternative A Rate of reaction is the collision rate of molecules in a unit time.	23.5	34.3
Alternative B Rate of reaction is the duration between the starting and finishing of reaction.	14.7	22.9
Alternative C Rate of reaction is the number of colliding atoms in a unit time.	8.8	5.7
Alternative D Rate of reaction is the change of reactants.	5.9	11.4
Alternative E* Rate of reaction is the decrease in concentration of reactants in a unit time.	47.1	25.7

*Correct Alternative

In the 17th question, the students were asked to choose which one is a true statement related to catalyst. Before the treatment, 29.4 % of the students in the experimental group and 25.7 % of the students in the control group had the misconception that catalyst was an intermediate substance which participated in a reaction as a reactant but got out without affecting the reaction. After the treatment, 67.6 % of the students in the experimental group answered this question correctly. However, 31.4 % of the students in the control group selected the correct alternative for this question. Nevertheless, in the experimental group, 17.6 % of the students still had that misconception even after the treatment (Table 5.8).

Table 5.8 Percentage of Students' Responses to Question 17

Question 17: Which statement related to catalyst is correct?	Percentage of Students' Responses (%)	
	Experimental Group	Control Group
Alternative A Catalyst is an intermediate substance which participates in a reaction as a reactant but gets out without affecting the reaction.	17.6	40.0
Alternative B Catalyst is a substance which decreases forward reaction rate and backward reaction rate.	8.8	11.4
Alternative C Catalyst is a substance which is formed during a reaction and then is consumed.	2.9	14.3
Alternative D* Catalyst is a substance which decreases activation energy of a reaction rate.	67.6	31.4
Alternative E Catalyst is an external substance which decreases enthalpy change of a reaction (ΔH).	2.9	2.9

*Correct Alternative

In the 22nd question, the students were asked to select the wrong statement related to a reaction carried out at two steps. Before the treatment, 38.2 % of the students in the experimental group and 31.4 % of the students in the control group chose the alternative as the wrong statement which was actually true. This alternative was related to the relationship between pressure change and reaction rate. After the treatment, while the percentage of the students who correctly answered this question was 97.1, this percentage value for the control group was 62.9.

In the 24th question, the students were asked to select the wrong statement related to a given potential energy diagram of a two-step reaction. Before the treatment, 29.4 % the students in the experimental group and 22.9 % of the students in the control group had the misconception that the fast step of a reaction has higher activation energy than the slow step of that reaction but after the treatment, 97.1 % of the students in the experimental group selected the correct alternative. However, in the control group, 48.6 % of the students answered this question correctly.

However, in the 13th question which is related to the graph of the relationship with rate of a reaction and time, there was a contradictory result. While the percentage of the students in the control group who answered this question correctly (11.4 %) was lower than the percentage of the students in the experimental group (14.7 %) before the treatment, the percentage of the students who selected the correct alternative in the control group (25.7 %) was higher than that of in the experimental group (14.7) after the treatment. This contradictory result might be resulted in not enough focusing on the change in reaction rate with time during the instruction in the experimental group.

As a result, the understanding levels of the students taught with conceptual change based instruction accompanied by demonstrations was higher than that of the students taught with traditionally designed chemistry instruction.

5.2.2 Null Hypothesis 2

This hypothesis stating that there is no significant mean difference between post-test mean scores of males and females with respect to their understanding of rate of reaction concepts when science process skill is controlled as a covariate was tested by using Analysis of Covariance (ANCOVA).

Before conducting ANCOVA, the assumptions of ANCOVA were tested. The assumptions of ANCOVA are the following:

i. Independence of observations within and between groups,
ii. Normality of sampling distribution,
iii. Equal variances,
iv. No custom interaction between independent variable and covariate,
v. Significant correlation between dependent variable and covariate.

For the first assumption of ANCOVA, all tests were administered to the students in the standard conditions. In addition, it was assumed that there was no interaction within and between groups during the administration of the tests. For the second assumption of ANCOVA, the skewness and kurtosis values of post-RRCT scores (Table 5.1) of the students in both groups show that RRCT scores are normally distributed. For the third assumption of ANCOVA, Levene's Test of Equality result (F (1, 67 = .02, p<.05) show that the variances of the post-RRCT scores of the students in both groups were not equal (Table 5.2). Even though this assumption was not met, the analysis was performed.

For the fourth assumption of ANCOVA that there should not be a custom interaction between independent variable and covariate, the results in Table 5.9 show that there is no custom interaction between gender and students' science process skill test scores (F (1, 1) = 0.463, p>.05). Since the p value (0.499) is too close to 0.05, it can be assumed that there is no custom interaction between gender and students' science process skill test scores.

Table 5.9 Test of Between-Subjects Effects for Post-RRCT (Gender-SPST)

Source	df	SS	MS	F	p
Gender	1	8.943	8.943	0.452	0.504
SPST	1	67.238	67.238	3.402	0.070
Gender & SPST	1	9.142	9.142	0.463	0.499

For the fifth assumption, the correlation between students' rate of reaction concept test scores and science process skill test scores was calculated. The result presented in Table 5.4 points out that there is a significant correlation between these two scores of the students (r = .211, p<.05).

After testing all assumptions, ANCOVA was conducted. The results of the analysis were summarized in Table 5.5. The results show that there was no significant mean difference between post-test mean scores of females and males with respect to understanding of concepts of reaction rate when the science process skill is controlled as a covariate (F (1, 64) = .365, p> .05). The mean post-test scores with respect to rate of reaction concept test were 16.41 for females and 16.33 for males.

5.2.3 Null Hypothesis 3

This hypothesis stating that there is no significant effect of interaction between gender and treatment on students' understanding of rate of reaction concepts when science process skill is controlled as a covariate was tested by using Analysis of Covariance (ANCOVA). Table 5.5 also gives the results for the interaction effect on understanding of these concepts. The results ($F(1, 64) = .688$, $p > .05$) show that there was no significant interaction effect between gender and treatment on students' understanding of concepts of reaction rate.

5.2.4. Null Hypothesis 4

This hypothesis stating that there is no significant contribution of science process skills to understanding of rate of reaction concepts was tested by using Analysis of Covariance (ANCOVA). The results given in Table 5.5 ($F(1, 64) = 1.970$, $p > .05$) show that there was no significant contribution of science process skills to understanding of rate of reaction concepts. If the study were conducted with a larger sample or conducted in a longer time, a significant contribution of science process skills to understanding of rate of reaction concepts would be found.

5.2.5. Null Hypothesis 5

This hypothesis stating that there is no significant mean difference between post-test mean scores of the students taught with conceptual change based instruction accompanied by demonstrations and the students taught with traditionally designed chemistry instruction with respect to their achievement in rate of reaction concepts when science process skill is controlled as a covariate was tested by using Analysis of Covariance (ANCOVA).

Before conducting ANCOVA, the assumptions of ANCOVA were tested. The assumptions of ANCOVA are following:

i. Independence of observations within and between groups,
ii. Normality of sampling distribution,
iii. Equal variances,
iv. No custom interaction between independent variable and covariate,
v. Significant correlation between dependent variable and covariate.

For the first assumption of ANCOVA, all tests were administered to the students in the standard conditions. In addition, it was assumed that there was no interaction within and between groups during the administration of the tests. For the second assumption of ANCOVA, the skewness and kurtosis values of post-RRAT scores (Table 5.1) of the students in both groups show that RRAT scores are normally distributed. For the third assumption of ANCOVA, Levene's Test of Equality result ($F(3, 65) = 2.454$, $p>.05$) show that the variances of the post-RRAT scores of the students in both groups were equal (Table 5.10).

Table 5.10 Levene's Test of Equality of Error Variances for Post-RRAT

	F	df1	df2	P
Post-RRAT	2.454	3	65	.071

For the fourth assumption of ANCOVA that there should not be a custom interaction between independent variable and covariate, the results in Table 5.11 show that there is no custom interaction between treatment and students' science process skill test scores ($F(1, 1) = 0.391$, $p>.05$).

Table 5.11 Test of Between-Subjects Effects for Post-RRAT (Treatment-Gender)

Source	df	SS	MS	F	p
Treatment	1	0.003	0.003	0.001	0.981
SPST	1	24.895	24.895	4.474	0.038
Treatment & SPST	1	2.176	2.176	0.391	0.534

For the fifth assumption, the correlation between students' post- rate of reaction achievement test scores and science process skill test scores was calculated. The result presented in Table 5.12 points out that there was a significant correlation between these two scores of the students (r=.279, p<.05).

Table 5.12 Correlation between Post-RRAT Scores and SPST Scores

		Post-RRAT	SPST
Post-RRCT	Pearson Correlation	1	0.279*
	Sig.		0.020
	N	69	69
SPST	Pearson Correlation	0.279*	1
	Sig.	0.020	
	N	69	69

*significant at .05

After testing all assumptions, ANCOVA was conducted. The results of the analysis are summarized in Table 5.13. The results show that there was a significant mean difference between post-test mean scores of the students taught with conceptual change based instruction accompanied by demonstrations and the students taught with traditionally designed chemistry instruction with respect to their achievement in rate of reaction concepts when science process skill is controlled as a covariate ($F(1,64) = 8.455$, $p < .05$). The experimental group students scored significantly higher than the control group students in RRAT.

Table 5.13 ANCOVA Summary of Post-RRAT

Source	df	SS	MS	F	p
Covariate (SPST)	1	24.807	24.807	4.370	0.041
Gender	1	0.307	0.307	0.054	0.817
Treatment	1	47.998	47.998	8.455	0.005
Gender & Treatment	1	0.257	0.257	0.045	0.832
Error	64	363.316	5.667		

5.2.6 Null Hypothesis 6

This hypothesis stating that there is no significant mean difference between post-test mean scores of males and females with respect to their achievement in rate of reaction concepts when science process skill is controlled as a covariate was tested by using Analysis of Covariance (ANCOVA).

Before conducting ANCOVA, the assumptions of ANCOVA were tested. The assumptions of ANCOVA are following:

i. Independence of observations within and between groups,
ii. Normality of sampling distribution,
iii. Equal variances,
iv. No custom interaction between independent variable and covariate,
v. Significant correlation between dependent variable and covariate.

For the first assumption of ANCOVA, all tests were administered to the students in the standard conditions. In addition, it was assumed that there was no interaction within and between groups during the administration of the tests. For the second assumption of ANCOVA, the skewness and kurtosis values of post-RRAT scores (Table 5.1) of the students in both groups show that RRAT scores are normally distributed. For the third assumption of ANCOVA, Levene's Test of Equality result ($F(3, 65) = 2.454$, $p>.05$) show that the variances of the post-RRAT scores of the students in the experimental and control group were equal (Table 5.10).

For the fourth assumption of ANCOVA that there should not be a custom interaction between independent variable and covariate, the results in Table 5.9 show that there is no custom interaction between gender and students' science process skill test scores ($F(1, 1) = 0.463$, $p>.05$). For the fifth assumption, the correlation between students' rate of reaction achievement test scores and science process skill test scores was calculated. The result presented in Table 5.12 points out that there is a significant correlation between these two scores of the students ($r=.279$, $p<.05$).

After testing all assumptions, ANCOVA was conducted. As shown in Table 5.13, the results show that there was not a significant mean difference between post-test mean scores of females and males with respect to achievement in rate of reaction concepts when science process skill is controlled as a covariate ($F(1, 64) = .054$, $p>.05$). The mean post-test scores were 10.57 for females and 10.43 for males.

5.2.7 Null Hypothesis 7

This hypothesis stating that there is no significant effect of interaction between gender and treatment on students' achievement in rate of reaction concepts when science process skill is controlled as a covariate was tested by using Analysis of Covariance (ANCOVA). The results presented in Table 5.13 show that there was no significant interaction effect between gender and treatment on students' achievement in rate of reaction concepts ($F(1, 64) = .045$, $p >.05$).

5.2.8 Null Hypothesis 8

This hypothesis stating that there is no significant contribution of science process skills to achievement in rate of reaction concepts was tested by using Analysis of Covariance (ANCOVA). The results given in Table 5.13 ($F(1, 64) = 4.370$, $p <.05$) show that there was a significant contribution of science process skills to achievement in the concepts of reaction rate.

5.2.9 Null Hypothesis 9

This hypothesis stating that there is no significant mean difference between the post-test mean scores of the students taught with conceptual change based instruction accompanied by demonstrations and the students taught with traditionally designed chemistry instruction with respect to their attitudes towards chemistry as a school subject was tested by using the two-way Analysis of Variance (ANOVA).

Before conducting ANOVA, the assumptions of ANOVA were tested. The assumptions of ANOVA are following:

i. Independence of observations within and between groups,
ii. Normality of sampling distribution,
iii. Equal variances.

For the first assumption of ANOVA, all tests were administered to the students in the standard conditions. In addition, it was assumed that there was no interaction within and between groups during the administration of the tests. For the second assumption of ANOVA, the skewness and kurtosis values of post-ASTC scores (Table 5.1) of the students in both groups show that ASTC scores are normally distributed. For the third assumption of ANOVA, Levene's Test of Equality result ($F(3, 65) = 1.270$, $p>.05$) show that the variances of the post-ASTC scores of the students in both groups were equal (Table 5.14).

Table 5.14 Levene's Test of Equality of Error Variances for Post-ASTC

	F	df1	df2	p
Post-ASTC	1.270	3	65	.292

After testing all assumptions, ANOVA was conducted. The results of this analysis were summarized in Table 5.15. The results show that there was a significant mean difference between post-test mean scores of the students taught with conceptual change based instruction accompanied by demonstrations (CCBIAD) and the students taught with traditionally designed chemistry instruction (TDCI) with respect to their attitudes towards chemistry as a school subject, ($F(1, 65) = 11.093$, $p<.05$). The experimental group students scored significantly higher than the control group students in ASTC ($\overline{X}$ (CCBIAD) = 63.17, $\overline{X}$ (TDCI) = 55.51).

Table 5.15 ANOVA Summary of Post-ASTC

Source	Sum of Squares	df	Mean Square	F	p
Group	953.913	1	953.913	11.093	.001
Gender	266.518	1	266.518	3.099	.083
Group*Gender	63.222	1	63.222	.735	.394
Error	5589.630	65	85.994		

5.2.10 Null Hypothesis 10

This hypothesis stating that there is no significant mean difference between post-test mean scores of males and females with respect to their attitudes towards chemistry as a school subject was tested by using the two-way Analysis of Variance (ANOVA).

Before conducting ANOVA, the assumptions of ANOVA were tested. The assumptions of ANOVA are following:

i. Independence of observations within and between groups,
ii. Normality of sampling distribution,
iii. Equal variances.

For the first assumption of ANOVA, all tests were administered to the students in the standard conditions. In addition, it was assumed that there was no interaction within and between groups during the administration of the tests. For the second assumption of ANOVA, the skewness and kurtosis values of post-ASTC scores (Table 5.1) of the students in both groups show that RRAT scores are normally distributed. For the third assumption of ANOVA, Levene's Test of Equality result ($F(3, 65) = 1.270$, $p>.05$) show that the variances of the post-ASTC scores of the students in both groups were equal (Table 5.14).

After testing all assumptions, ANOVA was conducted. As shown in Table 5.15, the results show that there was not a significant mean difference between post-test mean scores of females and males with respect to their attitudes towards chemistry as a school subject ($F(1, 65) = 3.099$, $p> .05$). The mean of post-ASTC scores were 61.37 for females and 57.32 for males.

5.2.11 Null Hypothesis 11

This hypothesis stating that there is no significant effect of interaction between gender and treatment on students' attitudes towards chemistry as a school subject was tested by using two-way Analysis of Variance (ANOVA). Table 5.15 also presents the interaction effect on attitudes towards chemistry as a school subject. The results ($F (1, 65) = .735$, $p >.05$) show that there was no significant interaction effect between gender and treatment on students' attitudes towards chemistry as a school subject.

5.3 Students' Interviews

Six students from each group were chosen based on their pre- concept test results to be interviewed about the misconceptions in rate of reaction concepts. The students who have low scores were chosen as interviewee. The students determined in the experimental group were numbered from 1 to 6 and the students determined in the control group were numbered from 7 to 12. The interview questions were prepared to determine students' misconceptions after treatment. Therefore, they were prepared by considering students' difficulties in rate of reaction and factors affecting the rate of reaction. What each interview question was about and what the interview results for that question show are presented below.

1st interview question: In this question, the students were asked how they would define rate of a reaction. Most of the students from the experimental group defined the rate of a reaction correctly. For example, the 1st interviewee defined the rate of a reaction as "the decrease amount of the reactants' concentration in a unique time interval". Only one of the students in the experimental group had a misconception about what rate of reaction is. He said that rate of reaction was the time of products' formation. However, the students from the control group had difficulties while explaining rate of reaction. Some of them defined rate of reaction as the time in which the reaction took place. 11th and 12th interviewee said that the rate of reaction is the ratio between the concentration of products and the concentration of reactants. Furthermore, the 12th interviewee also defined the rate of reaction as "colliding of the molecules during a reaction". The 10th interviewee had a misconception about the concept. She said that in a reaction, if the total numbers of moles of the reactants and products were equal to each other, that reaction had no rate.

2nd interview question: In this question, the students were asked how they could increase the rate of a reaction. The 1st interviewee from the experimental group replied this question as in the following:

> Interviewee: I use catalyst to increase the temperature.
>
> Interviewer: Why do these increase the rate of reaction? For example, what happens when you use catalyst?
>
> Interviewee: When the catalyst is used, the activation energy of that reaction decreases. So, the rate of that reaction increases.
>
> Interviewer: Why does the increase in temperature increase the rate of reaction?
>
> Interviewee: Because the average rates of the molecules increase when the temperature is increased.

The 2nd interviewee also said she could use catalyst to increase the rate of a reaction. She explained this as:

> "When a catalyst is added into a reaction, the catalyst changes the mechanism of the reaction and so the rate of reaction increases."

All students from the experimental group mentioned the factors affecting the rate of reaction and explained why these factors increase the rate of reaction. All students talked about temperature, catalyst, and concentration. Some of them mentioned the surface area as an effective factor influencing the rate of reaction, as well. For instance, 4th interviewee said that:

> "To increase the rate of a reaction, I increase the temperature. When the temperature increases, the kinetic energies of the molecules increase and the numbers of colliding molecules do so thus the rate of reaction increases."

The 5th interviewee said that:

> "If there is a solid matter in the reaction, I cut solid matter into small pieces. So the surface area is increased and the molecules might often crash. Therefore, the rate of reaction increases."

The students from the control group also mentioned the factors such as temperature, concentration, catalyst, and surface area while replying this question. However, they had difficulties in explaining the reasons. Some of them had misconceptions about the effects of these factors and some of them could not give any reason for the effects of some factors. For example, 8th interviewee said that:

> "When the temperature is increased, the phase of matters transform from solid into liquid. Therefore, rate of reaction increases."

The 12th interviewee said that:

> "When the number of reactant moles is increased, rate of reaction is decreases. Because when the amount of reactants was high, they could not collide with each other."

3rd interview question: In this question, the students were asked how increase in temperature would affect rate of reaction in both endothermic and exothermic reactions. Both the students from the experimental group and the control group had misconception on this subject. The students' misconception related to this issue was that "in the endothermic reactions, when temperature is increased, rate of reaction increases because endothermic reactions take in energy during the reaction and in the exothermic reactions, increase in temperature decreases the rate of reaction because energy is given out". Only the 4th interviewee in the experimental group gave the answer correctly with its explanation and said that:

> "Increase in temperature increases rate of both endothermic and exothermic reactions. Because the increase in temperature affects all reactions in the same way and increases their rates."

4th interview question: In this question, a reaction where a gas C was formed from A and B gases was shown and then this reaction was said to occur in one step. Then, the students were asked what the effect of some changes such as using catalyst, adding more reactant of A, increasing temperature was on activation energy, number of effective collision, and rate of that reaction. Most of the students from the experimental group answered these questions correctly. For example, when the effect of catalyst on activation energy was asked, only the 3rd student gave a wrong answer. He said that catalyst did not affect activation energy of a reaction. When the effect of catalyst on the number of effective collisions and on the rate of reaction was asked, all students from the experimental group answered this question correctly. However, most of the students from the control group could not reply this question accurately. Some of them stated that when a catalyst was used in reaction, activation energy would increase and some of them could not give any answer to this question. Only 7th interviewee said that the activation energy would decrease when a catalyst was added into a reaction. Although the students mentioned that catalyst would increase activation energy, they said that this factor would increase both the number of effective collisions and the rate of reaction. For example, the 10th interviewee said that:

> "When catalyst is added into a reaction, activation energy increases. In this reaction, since the mole numbers of reactants and products are equal to each other, the rate of reaction does not change."

Then, the students were asked what the effect of adding more "A" gas on the activation energy, the number of effective collisions and the rate of reaction was. Only the 4th interviewee gave a wrong answer to the effect of increase in the concentration of a reactant on activation energy of the reaction. She explained this effect as:

> "When more "A" gas is added to the reaction, reaction occurs faster. If the reaction occurs faster, this means that activation energy of that reaction decreases."

The other students from the experimental group answered this question in a correct way. All of them explained that increase in concentration of a reactant would increase the number of effective collisions and the rate of reaction. However, only the 11th interviewee replied this question correctly. The other students in the control group had different misconceptions about the effect of concentration on activation energy. For example, the 7th interviewee stated that:

> "If catalyst is used in a reaction, the rate of that reaction increases. Since the rate of reaction increases, its activation energy decreases."

An excerpt from the interview with the 9th interviewee is as follows:

> Interviewer: When "A" gas is added into the reaction, how does the activation energy change?
>
> Interviewee: It increases.
>
> Interviewer: Why does it increase? What do you think about that?

Interviewee: When we add “A” gas, the collision numbers of “A” gas increases. Thus, the energies of the molecules increase.

The 11th interviewee said that the rate of reaction and the effective collision number of molecules would not change when more “A” gas was added because the mole number of the product was increased at the same time. That is to say, this student had a misconception that reactant concentration change would not affect the rate of reaction. Also, the 12th interviewee said that increase in reactant concentration would increase rate of reaction but she could not give a reasonable explanation about this effect. She said that:

“When we add “A” gas, the mole numbers of the products also increase. Thus, the temperature increases so the rate of reaction increases.”

After that, the students were asked about the effect of increase in temperature on activation energy, the number of effective collisions and the rate of reaction. Except for the 4th interviewee, all of the students from the experimental group gave the correct answer to this question. The 4th interviewee had a misconception about the correlation between the activation energy and the rate of reaction. This misconception was that “there is a reverse ratio between the activation energy and the rate of reaction. When the rate of reaction increases this always means the activation energy of the reaction decreases.”

The students in the experimental group explained the reasons why an increase in temperature would increase the rate of reaction. For instance, the 1st interviewee said that:

“When the temperature is increased, the kinetic energies of the molecules increase. Thus the rate of that reaction increases.”

On the other hand, most of the students from the control group had some misconceptions about the effect of temperature on the activation energy, the number of effective collisions, and the rate of reaction. For instance, the 9th interviewee said that:

“The increase in temperature increases concentration of substances. So the rate of reaction increases. The increase in temperature increases the activation energy because there is a direct proportion between temperature and activation energy.”

5th interview question: In this interview question, the students were given a reaction where "Z" gas was formed of "X" gas and "Y" solid. Then they were asked to explain how the rate of reaction would change when the "Y" solid was cut into small pieces. Most of the students in the experimental group answered this question correctly and explained the effect of surface area on the rate of reaction. However, two of them (1st and 3rd interviewees) had a misconception that the changes in particle size of solid reactants in a reaction would not affect the rate of reaction. On the other hand, most of the students in the control group had some misconceptions. For example, the 11th interviewee said that:

> "When the solid reactant is cut into small pieces, the reaction slows down because when a solid substance is cut into small pieces the reaction should slow down."

The answer of the 12th interviewee to this question is as follows:

> "The rate of reaction increases because when "Y" is cut into small pieces, the number of molecules increases. Thus, the rate of reaction increases."

6th interview question: In this question, the students were shown the reaction which caused depletion of ozone in atmosphere. This reaction had a mechanism with two steps; fast and slow steps. Also NO_2 was middle product and NO was catalyst in this reaction. First, the students were asked on which step they wrote the rate equation that reaction and which step had lower activation energy. Both the students in the experimental group and those in the control group gave the answer of "slow step" for the rate equation question. Although some of the students in the control group could make that explanation, most of the students in the experimental group made a reasonable explanation of it. For instance, 3rd interviewee said that:

> "I write rate equation based on the slow step. The reaction should occur according to slow step. A man who walks faster than another man should keep up with that man walking slower. In the reactions it is like that. So we write it based on slow step."

For the question on relationship between activation energy and rate of steps, all students in the experimental group gave the correct answer, "fast step". However, some students in the control group said that slow step had lower activation energy. For example, the excerpt of the interview with 9th interviewee is as follows:

> 9th interviewee: The slow step has lower activation energy.
>
> Interviewer: Why do you think about the reason of it?
>
> 9th interviewee: the reaction of which activation energy is higher takes place faster. Since first step is slow, its activation energy should be lower than the other.

In this interview question, also the students were asked whether there was a middle product and catalyst or not, and if there was which one? From the experimental group, only one student had misconceptions about middle product and catalyst. He confused middle product and catalyst and defined catalyst as a middle product which was formed in a step and was consumed in another step. The students in the control group had also some misconceptions on middle product and catalyst. For example:

> 9th interviewee: Middle product reacts when the reaction starts to occur but it is not got at the end of the reaction, it is consumed. It does not include in the reaction. Here the middle product is NO.
>
> 10th interviewee: Middle product is the substance which is got at the end of reaction without any change.

7th interview question: In this interview question, a reaction was shown to the students. This reaction was formation of C from A and B. The students were asked how the concentration of A would change during the reaction and how the rate of the reaction would change as well. Some of the students from both experimental and control group said that the concentration of A would decrease during reaction. However, some of them in both groups had misconceptions about concentration of reactants and rate of reaction during time. For example, 10th interviewee said that: "If any change is not done during a reaction, rate of that reaction will be same, will not change. It occurs with the speed it had in the beginning." 2nd interviewee said that "Since A and B will form C, the reaction gets faster during time. That is when reactants are consumed, this means reaction occurs fast."

Based on the results of interview analysis, Table 5.16 was constructed. This table shows the misconceptions about the rate of reaction concepts of the students in both groups. It can be seen also in this table, the students in the experimental group still had some misconceptions about the concepts even after the instruction.

Table 5.16 The Misconceptions Determined based on Interview Analysis

Number of Interview Question	Experimental Group	Control Group
1	The rate of reaction is the time of products' formation.	The rate of reaction is the time in which the reaction takes place. The rate of reaction is the ratio between the concentration of products and the concentration of reactants. The rate of reaction is the colliding of the molecules during a reaction. If the total numbers of moles of the reactants and products are equal to each other, that reaction has no rate.
2		When the temperature is increased, the phase of matters transform from solid into liquid. Therefore, rate of reaction increases. When the number of reactant moles is increased, rate of reaction is decreases. Because when the amount of reactants was high, they could not collide with each other.
3		In the endothermic reactions, when temperature is increased, rate of reaction increases because endothermic reactions take in energy during the reaction and in the exothermic reactions, increase in temperature decreases the rate of reaction because energy is given out.
4	Catalyst does not affect activation energy of a reaction.	When a catalyst is used in reaction, activation energy will increase. When catalyst is added into a reaction, activation energy increases. In this reaction, since the mole numbers of reactants and products are equal to each other, the rate of reaction does not change.

Table 5.16 (continued)

Number of Interview Question	Experimental Group	Control Group
		If catalyst is used in a reaction, the rate of that reaction increases. Since the rate of reaction increases, its activation energy decreases.
	When more reactant is added to the reaction, reaction occurs faster. If the reaction occurs faster, this means that activation energy of that reaction decreases.	When the concentration of a reactant increases, the collision numbers of that reactant increases. Thus, the energies of the molecules increase and activation energy of that reaction increases.
		The rate of reaction and the effective collision number of molecules would not change when more reactant was added because the mole number of the product was increased at the same time.
	There is a reverse ratio between the activation energy and the rate of reaction. When the rate of reaction increases this always means the activation energy of the reaction decreases.	The increase in temperature increases concentration of substances. So the rate of reaction increases. The increase in temperature increases the activation energy because there is a direct proportion between temperature and activation energy.
	The change in particle size of solid reactant in a reaction does not affect the rate of that reaction.	When the solid reactant is cut into small pieces, the reaction slows down.
5		The rate of reaction increases because when the solid substance is cut into small pieces, the number of molecules increases. Thus, the rate of reaction increases.
		The slow step has lower activation energy
6	Catalyst is formed in a step and is consumed in another step.	Middle product is the substance which is got at the end of reaction without any change.
7	If any change is not done during a reaction, rate of that reaction will be same, will not change. It occurs with the speed it had in the beginning.	The reaction gets faster during time. That is when reactants are consumed, this means reaction occurs fast.

5.4 Classroom Observations

The observations were performed in order to ensure treatment verification in both experimental and control group during the treatment. The researcher observed how the treatment was implemented, how students' reactions to the treatment were, and how the interaction between students and teacher in both groups was.

The treatment was conducted over four weeks in two classrooms at a public high school in Ankara. The researcher was present at all 45 minutes sessions in both groups just by sitting on the back side of the classrooms silently and by observing the students and the teacher and taking notes with respect to treatment verification during these observations. She did not participate in any part of the sessions during the treatment.

In the experimental group, the teacher used conceptual change based instruction accompanied by demonstrations. During the instruction, the teacher performed all conditions of conceptual change approach (dissatisfaction, intelligibility, plausibility, and fruitfulness). She used totally six demonstrations related to the factors affecting rate of reaction in intelligibility phase as planned before by the researcher. In the beginning of conceptual change based instruction, the teacher had some difficulties in managing classroom because the students made some noisy during demonstrations and discussion. In the later sessions, the students were familiar with conceptual change based instruction and demonstrations. Thus, the teacher could control the students during instruction. The students in the experimental group were so reluctant to participate in discussion sessions especially while the teacher was performing demonstrations. To watch the demonstrations and discuss about them motivated the students to participate in classroom discourse. The teacher also gave daily life examples about the concepts and encouraged students to give some examples and discuss on these examples.

In the control group, the teacher used traditionally designed chemistry instruction. She mainly used lecturing method and solved questions related to the subjects taught. She also used discussion method while explaining concepts. However, she did not consider students' misconceptions during sessions. Students were not reluctant to participate in discussions. When the teacher tried to form a discussion environment, students began to make noisy by talking each other. Just a few students participated in discussion and solving questions parts during instruction. In general, students' motivation and engagement to lessons were low.

As a result of observation analysis, it was concluded that conceptual change based instruction accompanied by demonstrations was more effective than traditionally designed chemistry instruction in drawing students' attention to the lesson, motivating them to participate in sessions during instruction, and thus enhancing them to be more active in the classroom.

5.5 Summary of the Results

In the light of all analyses results, the following conclusions can be reached:

1. The conceptual change based instruction accompanied by demonstrations caused a significantly better acquisition of scientific conceptions related to rate of reaction and elimination of misconceptions than the traditionally designed chemistry instruction.
2. The conceptual change based instruction accompanied by demonstrations caused a significantly better achievement in rate of reaction subject than the traditionally designed chemistry instruction.

3. There was no significant effect of gender on students' understanding of rate of reaction concepts, their achievement in rate of reaction concepts, and their attitudes toward chemistry as a school subject.

4. The conceptual change based instruction accompanied by demonstrations caused more positive attitudes toward chemistry as a school subject than the traditionally designed chemistry instruction.

CHAPTER VI

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

This chapter presents summary of the study, discussion of the results presented in Chapter V, implications with respect to teaching and learning, and recommendations for further studies.

6.1 Summary of the Study

At the outset, the literature related to students' misconceptions about rate of reaction concepts was examined. Then, in order to determine students' misconceptions about this subject, a Rate of Reaction Misconception Test was prepared according to the related literature and administered to 11th and 12th grade students. Then, the concept and achievement tests to be applied in the study, lesson plans and instructional activities were designed by considering both the results of the misconception test and the related literature review. The main purpose of this study is to investigate the effectiveness of conceptual change based instruction accompanied by demonstrations on 11th grade students' understanding of rate of reaction concepts and their attitudes toward chemistry as a school subject. Sixty nine 11th grade students from two intact classes of a chemistry teacher participated in this study. One of these classes was assigned as experimental group and the other as control group. The experimental group consisting of 34 students was instructed with conceptual change based instruction accompanied by demonstrations while the control group consisting of 35 students was instructed with a traditionally designed method. The study was conducted over four weeks. At the beginning of the study, RRCT, RRAT, ASTC, and SPST were administered to the students in both groups as pre-tests in order to determine whether there was a difference between the two groups. The results of independent t-test analysis show that before the instruction there was no significant mean difference between the experimental group and the control group with respect to their understanding of rate of reaction concepts, achievement in rate of reaction subject, attitudes toward chemistry, and science process skills. After the treatment, in order to examine the effect of conceptual change based instruction accompanied by demonstrations, RRCT, RRAT, and ASTC were administered to both student groups as post-tests. ANCOVA and two-way ANOVA were used to analyze the results.

6.2 Discussion of the Results

Rate of reaction is a difficult subject for students to understand. This subject is also important for students to understand other chemical concepts, especially related to chemical equilibrium in which students have difficulties as well (Banerjee, 1995). Because of the abstract nature of the concepts in rate of reaction, students have difficulties while learning this topic. The source of these difficulties is their misconceptions about the rate of reaction concepts (deVos & Verdonk, 1986; Justi, 2002). Therefore, the researcher prepared a misconception test related to rate of reaction concepts and administered it to students with the aim of determining their misconceptions. When these tests were examined, students were seen to have similar misconceptions detected in the literature (e.g. Cakmakci, 2005; Calik et al., 2010). These misconceptions were related to the definition of rate of reaction, factors affecting the rate of a reaction such as temperature, catalyst, and concentration. For example, many students thought that catalyst is an intermediate substance. Another misconception is that rate of reaction is the time between the beginning and finishing of a reaction. With respect to students' establishment of meaningful relationships between chemical and mathematical models of chemical kinetics, how teachers and textbooks represent models of reaction rate might be studied. Investigation of the possible reasons for students' difficulties in the area of chemical kinetics, such as their ability to interpret diagrams and their use of words such as catalyst or activation energy would also contribute significantly to the related literature.

Research in science education generally aims to investigate the effects of teaching strategies on students' learning of science. Some research focuses on teaching strategies challenging students' misconceptions (e.g. Hewson & Hewson, 1984; Niaz, 1995). After students' misconceptions are noticed, they should be eliminated in order to enhance students' understanding rate of reaction concepts. Substantial research points out that traditional instruction which includes rote memorization of facts and principles, and application of solving problems is not an effective instructional method and that better understanding can be promoted with development in students' conceptual understanding. Zoller (1993) argues that traditional chemistry instruction may improve students' low-order cognitive skills but is not effective for improving their higher-order cognitive skills. Therefore, in this study, instruction was designed based on the conceptual change method accompanied by demonstrations, and the effect of this instruction on 11^{th} grade students' understanding of rate of reaction concepts was investigated. While the experimental group was exposed to conceptual change based instruction, the control group was exposed to traditional chemistry instruction. The results of the statistical analyses show that conceptual change based instruction accompanied by demonstrations resulted in significantly better understanding of rate of reaction concepts than traditionally designed chemistry instruction.

In the experimental group, the teacher applied four conditions of accommodation to occur (Posner et al., 1982). Learning requires either just adding new conception to the previous ones or restructuring existing conceptions or even replacing them with new ones. Therefore, firstly, students were asked some questions from daily life about key concepts in order to activate their misconceptions. They were encouraged to discuss in the classroom environment by giving them a chance to share their ideas. During this discussion, the aim was to make students aware of their different thoughts about the concepts. They had difficulties in explaining their answers by using their existing conceptions. Thus, students were dissatisfied with their misconceptions (dissatisfaction). Then, the instruction continued with a demonstration related to the concept in order to explain the phenomenon. The demonstrations used during instruction not only allowed students to see the scientific events but also motivated them to participate actively in classroom discourse. The teacher also made scientific explanations about the concepts to clarify them for the students by focusing on students' misconceptions (intelligibility). After that, the teacher tried to explain why students' ideas were wrong. She also solved numerical problems to have them practice about the concepts. By encouraging students to solve related numerical problems and giving daily life examples, she tried to make the concepts plausible for the students (plausibility). Finally, in order to make the concepts fruitful for the students, the teacher provided opportunities to apply new conceptions to different examples through homework (fruitfulness). The status of an idea shows the degree to which a person who has that idea knows its meaning (intelligibility), accepts it as true (plausibility), and finds it useful for solving other problems or suggesting new ideas (fruitfulness). The more an idea meets these conditions, the more its status raises. Therefore, activities which are designed to raise the status of ideas are related to teaching for conceptual change. (Hewson, 1991). As noticed, the students in the experimental group were encouraged to participate in classroom discourse actively during the instruction by considering their misconceptions and promoting conceptual change in the subject of rate of reaction.

However, traditionally designed chemistry instruction was used in the control group. The teacher mostly used the lecturing method during the instruction. She created a discussion environment for the students. When the students did not understand the subject, they asked questions and the teacher explained by providing daily life examples. She also solved numerical problems to have the students practice about the concepts. However, the teacher taught the subjects without considering students' misconceptions and their previous knowledge. That is to say, the students were mainly passive during the instruction. When the instructions in both groups were taken into consideration, it goes without saying that considering students' misconceptions and promoting conceptual change in their conceptions by using demonstrations are the main differences between the experimental and the control group. These points might be the reasons for the effectiveness of conceptual change based instruction on students' better understanding of the scientific concepts. Substantial research from the literature (e.g. Abraham & Williamson, 1994; Andersson & Bach, 1996; Alkhawaldeh, 2007; Cetin et al., 2009; Smith et al., 1993; Tastan, Yalcinkaya, & Boz, 2008; Vosniadou et al., 2001) also supports the finding related to the effectiveness of conceptual change based instruction.

Although conceptual change based instruction resulted in better understanding of rate of reaction concepts and overcoming misconceptions about this subject, the evaluation of statistical analyses and interviews indicate that some students in the experimental group still had some misconceptions even after the given instruction. There is evidence supporting this finding that misconceptions are robust and resistant to change (e.g. Novak, 1988; Taber, 2001).

In addition, this study aimed to explore the effectiveness of conceptual change based instruction accompanied by demonstrations on students' achievement in rate of reaction concepts. In addition to conceptual understanding, algorithmic understanding is of importance in chemistry learning (Suits, 2000) because chemistry learning also requires students to master algorithmization of chemical and mathematical processes. To this purpose, an achievement test consisting of algorithmic questions related to the concepts of rate of reaction was prepared and administered to both student groups. The results show that the students in the group that was instructed with conceptual change based instruction accompanied by demonstrations were more successful than those in the group exposed to traditionally designed chemistry instruction in Rate of Reaction Achievement Test. In order to promote conceptual understanding in chemistry, students need to be able to use algorithms in chemistry and understand chemistry principles at three levels which are symbolic, particulate, and macroscopic (Suits, 2000). In this study, the students in the experimental group were make to understand rate of reaction concepts at macroscopic level through the demonstrations used in the intelligibility phase of conceptual change. Therefore, it is not surprising that the experimental group students who had better understanding of rate of reaction concepts received higher grades in the achievement test than the control group students who were instructed with the traditional method.

Another purpose of this study is to investigate the effect of gender on students' understanding of rate of reaction concepts and their achievement with respect to this subject. The results indicate that there was no significant difference between male and female students with respect to their understanding of rate of reaction concepts and achievement in these concepts. There has been substantial research which has evidence supporting that gender has no significant effect on students' learning of scientific concepts (e.g. Azizoglu, 2004; Greenfield, 1997). Additionally, it was found that there was no significant effect of interaction between gender and treatment on students' understanding and achievement in the rate of reaction concepts. However, some research points out that gender had a significant effect on students' understanding of concepts (e.g. Cetin et al., 2009; Chambers & Andre, 1997).

Furthermore, in this study, the effect of conceptual change based instruction on students' attitudes toward chemistry as a school subject was investigated. The results show that the students instructed with conceptual change based instruction accompanied by demonstrations had more positive attitudes toward chemistry than those instructed with traditionally designed chemistry instruction. Classroom observations performed during the study also support this finding. The treatment lasted four weeks which is not a long term. Yet, a significant change in the experimental group students' attitudes toward chemistry was observed. The reason for the significant mean difference in attitudes might be the use of demonstrations during conceptual change based instruction in this group. Since the concepts related to rate of reaction were explained through some demonstrations, these concepts became more intelligible for the students. Demonstrations not only make students to be aware of their misconceptions (Chi & Roscoe, 2002) but also increase their motivation and interest to learn chemical concepts. Furthermore, in the experimental group, students were encouraged to share their ideas and participate in classroom discourse. The teacher tried to know students' misconceptions and to remedy them by promoting students to be active participants in the classroom. These might be other reasons for more positive attitudes in the experimental group students. There are some studies supporting that instructional method cause attitude change (e.g. Sungur & Tekkaya, 2003; Thompson & Soyibo, 2002; Uzuntiryaki, 2003).

Gender effect with respect to students' attitudes toward chemistry was also investigated in this study. The result of the analysis shows that there was no significant mean difference between male and female students with respect to their attitudes toward chemistry as a school subject. Furthermore, no significant interaction between gender and treatment on students' attitudes toward chemistry was found. There is some research supporting this finding regarding no gender difference with respect to attitudes toward chemistry (e.g. Salta & Tzougraki, 2004). On the contrary, some research addresses gender difference regarding attitudes toward chemistry. In some of these research, gender difference in attitudes toward chemistry was in favor of male students (e.g. Barnes et al., 2005; Francis & Greer, 1999; Jones et al., 2000; Simpson & Oliver, 1985) while in some, female students had more positive attitudes toward chemistry (e.g. Dhindsa & Chung, 1999).

6.3 Implications

In the light of the findings of this study, the following implications with respect to learning and teaching of chemistry, and curriculum applications are suggested:

1. Students' misconceptions affect their understanding of chemistry concepts since these misconceptions are an obstacle in the integration of new concepts into existing concepts. Therefore, teachers should identify students' misconceptions about the subject by applying misconceptions tests or interviewing students before the instruction and design the instruction by considering these misconceptions in order to remediate them.

2. Another source of students' misconceptions is textbooks including misconceptions. Therefore, writers of textbooks should consider students' possible misconceptions while writing these textbooks and teachers should be careful about that while using these textbooks in the classroom.

3. Teachers should design and use conceptual change based instruction, which is an effective way to promote students' meaningful understanding of chemical concepts, in their chemistry classroom.

4. Conceptual change based instruction not only enhances meaningful concept understanding but also encourages students to participate in classroom discourse through the tools used based on the conceptual change method.

5. Curriculum designers should also be aware of effectiveness of conceptual based instruction and they should take it into consideration while designing or revising the chemistry curriculum.

6. For teachers to able to use conceptual change based instruction, necessary importance should be given to conceptual change based instruction during teacher education and they should be trained through the use of in-service seminars related to this issue.

7. Using demonstrations in the chemistry classroom contributes to students' conceptual understanding since students have a chance to observe the chemical events regarding the subject. Demonstrations are also effective in drawing students' attention to lesson and motivate them to participate in the lesson. Therefore, teachers should use appropriate demonstrations during chemistry instruction.

8. In addition, curriculum designers and textbook writers should consider the importance of demonstrations in students' learning of chemistry and they should include some activities based on demonstrations in the chemistry curriculum and textbooks.

9. One of the aims of chemistry education is to develop positive attitudes toward chemistry in students because there is a significant relationship between students' achievement in chemistry and attitudes toward chemistry. Therefore, teachers should aim to develop students' attitudes toward chemistry besides their understanding of concepts in the classroom.

6.4 Recommendations

Based on this study, the following recommendations for further studies are suggested:

1. In order to generalize the results to a larger population, the study can be conducted at different type of high schools and with a larger sample size.

2. The effectiveness of conceptual change based instruction can be investigated through other studies to be conducted at different grade levels.

3. The effectiveness of conceptual change based instruction can be investigated with respect to students' achievement and understanding of other chemical concepts.

4. The effectiveness of other instructional tools different than demonstrations in conceptual change based instruction on students' achievement and understanding of rate of reaction concepts and on the elimination of students' misconceptions can be studied.

5. Instead of demonstrations, some videos with respect to these demonstrations about rate of reaction can be used and its effectiveness on students' understanding can be investigated.

6. Further research can be conducted with pre-service chemistry teachers in order to investigate their self efficacy in applying conceptual change based chemistry instruction.

7. Further studies can be conducted in order to examine other constructs in the affective domain such as self- efficacy, anxiety, and motivation of students.

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APPENDIX A

INSTRUCTIONAL OBJECTIVES REGARDING RATE OF REACTION

1. To define rate of reaction.
2. To explain collision theory.
3. To relate rates of chemical reactions to collisions between the particles reacting.
4. To describe activation energy.
5. Identify factors that affect the rates of chemical reactions.
6. To determine the rate law for a given reaction mechanism.
7. To determine a rate law and reaction mechanism from laboratory rate data.
8. To determine reaction orders using the method of initial rates.
9. To identify factors affecting rate of reaction.
10. To express the effect of concentration on rate of reaction.
11. To express the effect of temperature on rate of reaction.
12. To relate rate of reaction to surface area.
13. To explain the role of a catalyst during a reaction.
14. To calculate reaction rates, rate constant and reaction order from given time versus concentration data.
15. To understand that many reactions occur in steps or have mechanism.
16. To discriminate the step that determines the rate of reaction.
17. To discriminate the reaction intermediate and catalyst in a given reaction mechanism.
18. To identify activation energy and reaction mechanism on a potential energy diagram.

APPENDIX B

REAKSİYON HIZI KAVRAM YANILGISI BELİRLEME TESTİ

Aşağıda reaksiyon hızı konusuyla ilgili olan ve 10 sorudan oluşan bir test bulunmaktadır. Lütfen soruları dikkatli bir şekilde okuduktan sonra her birinin altında yer alan boşluğa yanıtlarınızı yazınız.

1. Ecem çaydanlığındaki kireci çıkarmak için her zaman kullandığı %4'lük asit çözeltisi içeren kireç sökücüsü yerine %6'lık asit çözeltisi içeren bir başka kireç sökücüsü kullanıyor ve çaydanlıktaki kirecin öncekine göre daha hızlı çıktığını gözlemliyor. Sizce bunun sebebi nedir? Yanıtınızı çarpışma kuramına dayandırarak açıklayınız.
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2. Reaksiyon hızı nedir?
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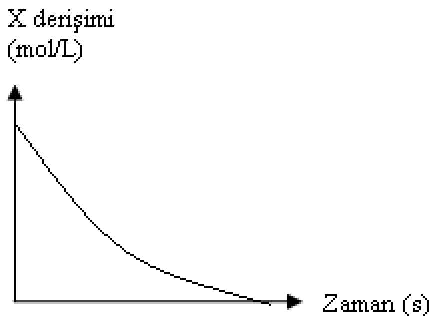
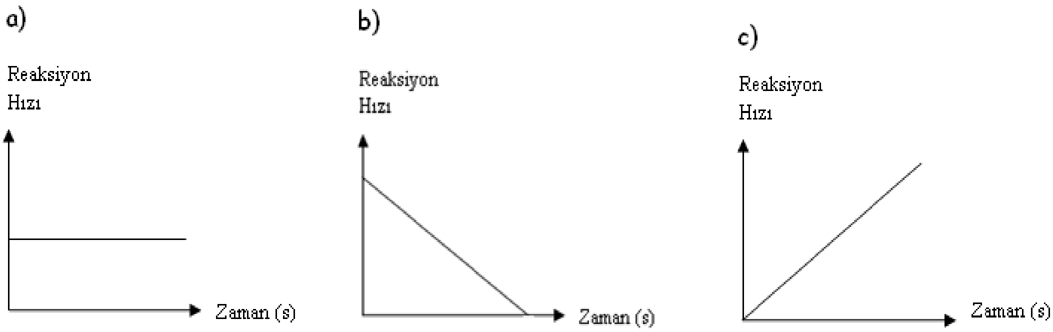
3. $2NO_{2(g)} + F_{2(g)} \rightarrow 2NO_2F_{(g)}$ reaksiyonunun hız ifadesi aşağıdakilerden hangisidir? Doğru yanıtı seçip nedenini açıklayınız.
   a) Hız = k $[NO_2]^2[F_2]$
   b) Hız = k $[NO_2][F_2]$
   c) Hız = k $[NO_2]^x[F_2]^y$
   d) Hız = k $[NO_2]^x$
   Çünkü,...
   ....

4. $X_{(suda)} + Y_{(suda)} \rightarrow Z_{(suda)}$ reaksiyonu için X'in derişiminin zamanla değişimini gösteren grafik yandaki gibidir. Buna göre, verilen reaksiyon için reaksiyon hızının zamanla değişimini gösteren grafik aşağıdakilerden hangisidir? Doğru yanıtı işaretledikten sonra nedenini açıklayınız.





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5. $2AB_{2(g)} + C_{2(g)} \rightarrow 2AB_2C_{(g)}$ reaksiyonu için Hız = k $[AB_2][C_2]$'dir. Buna göre aşağıdaki mekanizmalardan hangisi bu reaksiyonma aittir? Doğru yanıtı seçip nedenini açıklayınız.

a) 1. $AB_{2(g)} + C_{2(g)} \rightarrow AB_2C_{(g)} + C_{(g)}$ (Hızlı)
   2. $AB_{2(g)} + C_{(g)} \rightarrow AB_2C_{(g)}$ (Yavaş)

b) 1. $AB_{2(g)} + C_{2(g)} \rightarrow AB_2C_{(g)} + C_{(g)}$ (Yavaş)
   2. $AB_{2(g)} + C_{(g)} \rightarrow AB_2C_{(g)}$ (Hızlı)

c) 1. $C_{2(g)} \rightarrow 2C_{(g)}$ (Yavaş)
   2. $AB_{2(g)} + C_{2(g)} \rightarrow AB_2C_{(g)} + C_{(g)}$ (Hızlı)
   3. $AB_{2(g)} + C_{(g)} \rightarrow AB_2C_{(g)}$ (Hızlı)

d) 1. $AB_{2(g)} + C_{2(g)} \rightarrow AB_2C_{(g)} + C_{(g)}$ (Hızlı)
   2. $AB_{2(g)} + C_{(g)} \rightarrow AB_{2(g)}$ (Yavaş)

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6. Katalizör nedir? Bir reaksiyondaki fonksiyonunu dikkate alarak açıklayınız.
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7. Tek adımda gerçekleştiği bilinen $A_{(g)} + B_{2(g)} \rightarrow AB_{2(g)}$ reaksiyonunun gerçekleştiği ortamda bazı değişiklikler yapılıyor. Yapılan bu değişikliklerin oluşturduğu etkileri "artar", "azalır" ya da "değişmez" sözcüklerini aşağıdaki tabloda uygun yerlere yazarak belirtiniz.

	Aktivasyon enerjisi	Reaksiyon hız sabiti	Reaksiyon hızı	Etkin çarpışma sayısı
Katalizör kullanılması				
A gazının eklenmesi				
Hacmin azaltılması				
Sıcaklığın artırılması				

8. Atmosferdeki ozonun azalmasına neden olan $O_{3(g)} + O_{(g)} \rightarrow 2O_{2(g)}$ reaksiyonunun adımları şöyledir:

I. $O_{3(g)} + NO_{(g)} \rightarrow NO_{2(g)} + O_{2(g)}$ (Yavaş)

II. $NO_{2(g)} + O_{(g)} \rightarrow NO_{(g)} + O_{2(g)}$ (Hızlı)

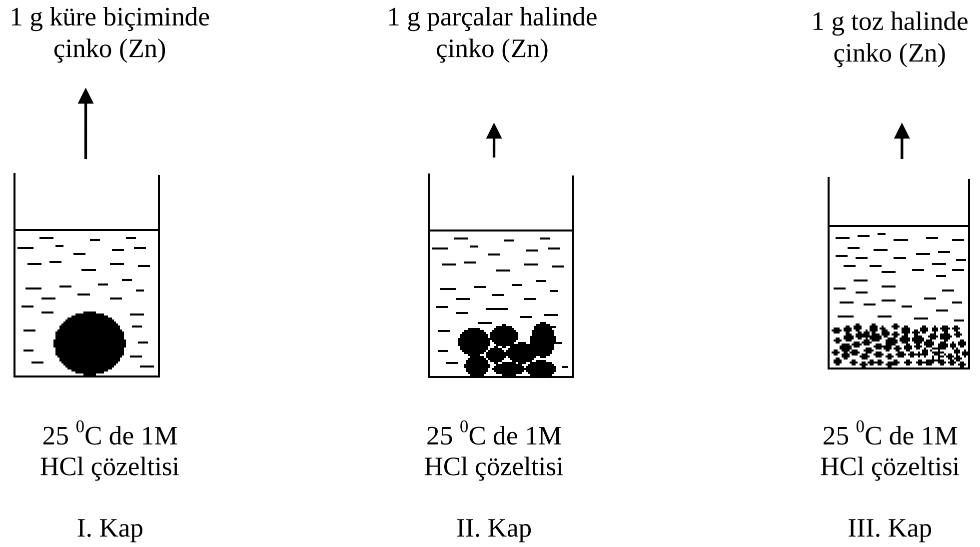
a) Bu reaksiyonun hız ifadesini yazınız.

....

b) Reaksiyondaki ara ürün ve katalizör hangi maddelerdir?

....

9. Aşağıdaki kapların her birinde $Zn_{(k)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(k)} + H_{2(g)}$ tepkimesi gerçekleşmektedir. Şekilde verilen bilgilere göre, üç kapta gerçekleşen tepkimelerin hızlarını karşılaştırınız ve hızların neden farklı olacağını açıklayınız.



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10. Bir reaksiyonu hızlandırmak için neler yaparsınız? Bu yaptıklarınız neden reaksiyonu hızlandırır açıklayınız.

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APPENDIX C

REAKSİYON HIZI KAVRAM TESTİ

Aşağıda "Reaksiyon Hızı" konusu ile ilgili 25 çoktan seçmeli sorudan oluşan bir kavram testi verilmiştir. Testteki her bir soru 5 seçenek içermektedir. Lütfen her bir soru için size en doğru gelen seçeneği işaretleyiniz. Başarılar.

1. $2N_2O_{(g)} + 3O_{2(g)} \rightarrow 2N_2O_{4(g)}$ reaksiyonu için N_2O, O_2 ve N_2O_4' e göre yazılan reaksiyon hızları (RH) için aşağıdakilerden hangisi doğrudur?

a) $RH_{N2O} = RH_{O2}$

b) $RH_{O2} = RH_{N2O4}$

c) RH_{N2O} = N_2O derişimindeki artma/zaman aralığı

d) RH_{O2} = O_2 derişimindeki artma/zaman aralığı

e) RH_{N2O4} = N_2O_4 derişimindeki artma/zaman aralığı

2. $Na_2CO_{3(k)} \rightarrow 2Na^{+}_{(suda)} + CO_3^{-2}{}_{(suda)}$ reaksiyonunun hızını ölçmek için kullanılabilecek en uygun yöntem aşağıdakilerden hangisidir?

a) Kütledeki değişim

b) Basınçtaki değişim

c) Özkütledeki artış

d) İletkenlikteki artış

e) Hacimdeki artış

3. Çarpışma teorisiyle ilgili olarak aşağıdakilerden hangisi doğrudur?

a) Bir reaksiyonun oluşması için çarpışan taneciklerin gaz fazında olması gereklidir.

b) Belli bir enerji düzeyinin üzerinde olan ve uygun geometride gerçekleşen çarpışmalar reaksiyon ile sonuçlanır.

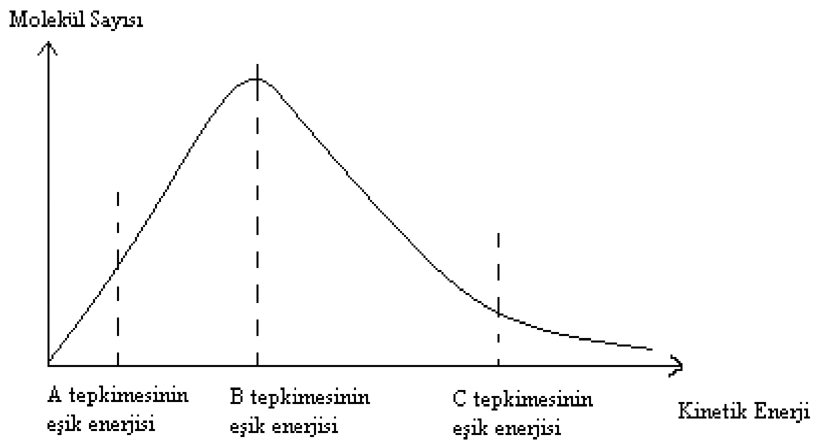
c) Gaz fazındaki tüm çarpışmalar reaksiyon ile sonuçlanır.

d) Reaksiyon hızı birim zamandaki çarpışma sayısıdır.

e) Reaksiyon hızı çarpışan taneciklerin yüzdesidir.

4. Aşağıdaki grafik aynı sıcaklıkta gerçekleşen üç farklı reaksiyonun kinetik enerji dağılımını göstermektedir.

Buna göre, bu reaksiyonların hızı (RH) aşağıdakilerden hangisinde doğru olarak karşılaştırılmıştır?



a) $RH_A > RH_B > RH_C$

b) $RH_A > RH_C > RH_B$

c) $RH_B > RH_C > RH_A$

d) $RH_C > RH_B > RH_A$

e) $RH_C > RH_A > RH_B$

5. Ca, Mg ve Ba elementleri asitlerle H_2 gazı açığa çıkarırlar. Bu elementlerin eşit molleri eşit hacim ve derişimdeki HCl ile reaksiyona girdiğinde,

I. Oluşan H_2'nin aynı şartlardaki hacmi

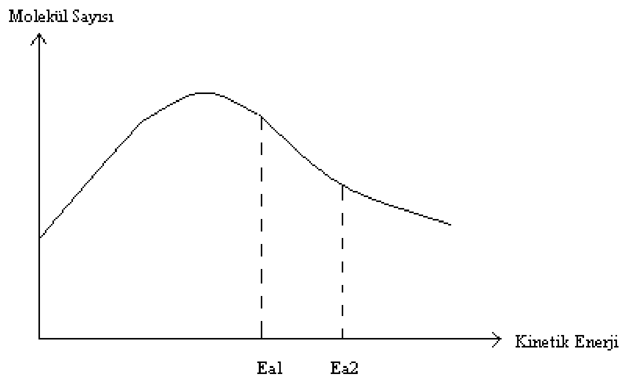
II. Kullanılan HCl'nin hacmi

III. Reaksiyon hızları

değerlerinden hangisi ya da hangileri farklı olur?

a) Yalnız I b) Yalnız II c) Yalnız III d) I ve II e) I, II, III

6. Yandaki grafik bir tepkimenin kinetik enerji dağılımını göstermektedir. Katalizörlü ve katalizörsüz olarak gerçekleşen tepkimenin bu iki farklı durumdaki aktivasyon enerjileri E_{a1} ve E_{a2} ile gösterilmiştir.



Buna göre aşağıdaki yargılardan hangisi ya da hangileri doğrudur?

I. E_{a1} katalizörlü tepkimenin aktivasyon enerjisidir.

II. E_{a2} tepkime hızı daha küçük olan tepkimenin aktivasyon enerjisidir.

III. Her iki durumdaki etkin çarpışma sayısı aynıdır.

a) Yalnız I b) Yalnız II c) Yalnız III d) I ve II e) I,II ve III

7. Bir tepkimede aşağıdakilerden hangisi sıcaklığa bağlı <u>değildir?</u>

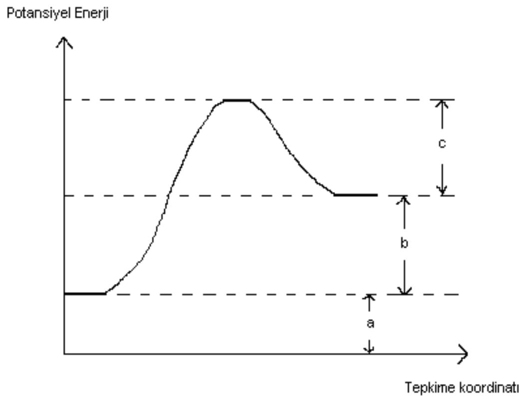
a) Aktivasyon enerjisi
b) Moleküllerin hızı
c) Moleküllerin kinetik enerjisi
d) Moleküllerin çarpışma sayısı
e) Aktivasyon enerjisine sahip molekül sayısı

8. $X_{(g)} + Y_{(k)} + Z_{(g)} \rightarrow A_{(k)} + B_{(g)}$ tepkimesi için aşağıdaki etkilerden hangisi tepkimenin hızını <u>artırmaz?</u>

a) X eklemek
b) Y eklemek
c) Z eklemek
d) Sıcaklığı yükseltmek
e) Kabın hacmini azaltmak

9. Yandaki şekilde bir tepkimenin potansiyel enerji-tepkime koordinatı grafiği verilmiştir.

Buna göre, geri tepkimenin aktifleşme enerjisinin değeri aşağıdakilerden hangisine eşittir?



a) a b) c c)a + b

d) b + c e) a + b + c

10. Bir reaksiyonda A ve B derişimleri reaksiyon hızını etkilemekte, C derişimi ise etkilememektedir.

4. dereceden olan bu reaksiyon, A derişimine göre 1. dereceden olduğuna göre, reaksiyon hız denklemi (RH) aşağıdakilerden hangisidir?

a) RH = k [A] $[B]^2$ [C]
b) RH = k [A] [B] $[C]^2$
c) RH = k [A] $[B]^3$ [C]
d) RH = k [A] $[B]^3$
e) RH = k $[B]^4$

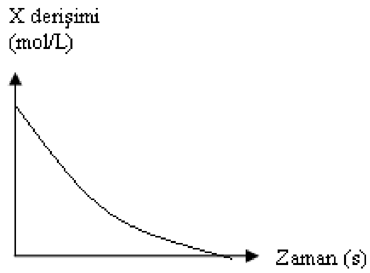
11. Sıcaklığın reaksiyon hızına etkisi ile ilgili aşağıdakilerden hangisi doğrudur?

a) Sıcaklık azaltılınca reaksiyon hızı azalır.
b) Sıcaklık azaltılınca endotermik reaksiyonların hızı azalırken, ekzotermik reaksiyonların hızı artar.
c) Sıcaklık değişikliği reaksiyon hızını etkilemez.
d) Sıcaklık artırılınca reaksiyon hızı azalır.
e) Sıcaklık sadece gaz halindeki maddelerin reaksiyon hızını artırır.

12. Tek adımda gerçekleştiği bilinen $A_{(g)} + B_{2(g)} \rightarrow AB_{2(g)}$ reaksiyonunun gerçekleştiği ortamda yapılan bazı değişikliklerin oluşturduğu etkiler aşağıdakilerden hangisinde doğru olarak verilmiştir?

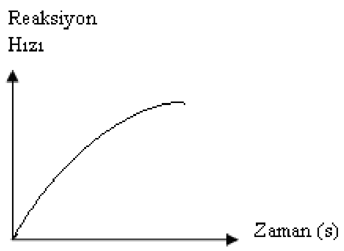
a) Katalizör kullanılınca aktivasyon enerjisi artmıştır.
b) Hacim azaltılınca reaksiyon hızı azalmıştır.
c) Sıcaklık artırılınca aktivasyon enerjisi değişmemiştir.
d) A gazı eklenince etkin çarpışma sayısı azalmıştır.
e) B_2 gazı eklenince reaksiyon hız sabiti artmıştır.

13. $X_{(suda)} + Y_{(suda)} \rightarrow Z_{(suda)}$ reaksiyonu için X'in derişiminin zamanla değişimini gösteren grafik yandaki gibidir.

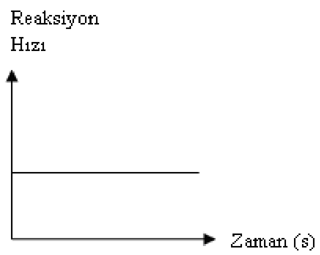


Buna göre, verilen reaksiyon için reaksiyon hızının zamanla değişimini gösteren grafik aşağıdakilerden hangisidir?

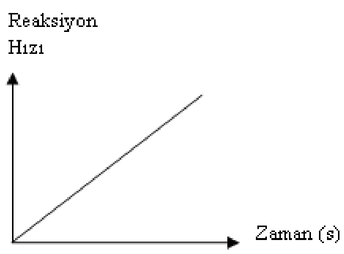
a)



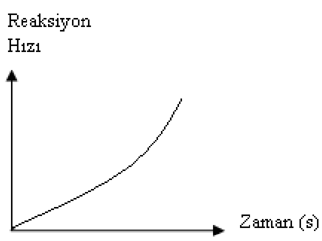
b)



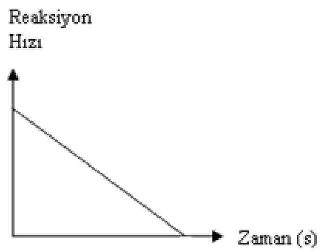
c)



d)



e)



14. $2X_{(g)} + Y_{(g)} \rightarrow 2Z_{(g)}$ reaksiyonu için hız eşitliği Hız = $k[X]^2$ şeklinde veriliyor.

Buna göre aşağıdakilerden hangisi yanlıştır?

a) Reaksiyon ikinci derecedendir.
b) Reaksiyon birden fazla adımda gerçekleşmektedir.
c) Y gazı eklendiğinde reaksiyon hızı artar.
d) X gazı eklendiğinde reaksiyon hızı artar.
e) Sıcaklık artırılınca reaksiyon hızı artar.

15. Atmosferdeki ozonun azalmasına neden olan $O_{3(g)} + O_{(g)} \rightarrow 2O_{2(g)}$ reaksiyonunun adımları şöyledir:

I. $O_{3(g)} + NO_{(g)} \rightarrow NO_{2(g)} + O_{2(g)}$ (Yavaş)

II. $NO_{2(g)} + O_{(g)} \rightarrow NO_{(g)} + O_{2(g)}$ (Hızlı)

Buna göre, bu reaksiyonun hız ifadesi aşağıdakilerden hangisidir?

a) Hız = k $[NO_2][O]$
b) Hız = k $[O_3][NO]$
c) Hız = k $[NO_2][O_2]$
d) Hız = k $[O_3][O]$
e) Hız = k $[O_2]^2$

16. Reaksiyon hızı ile ilgili olarak aşağıdakilerden hangisi doğrudur?

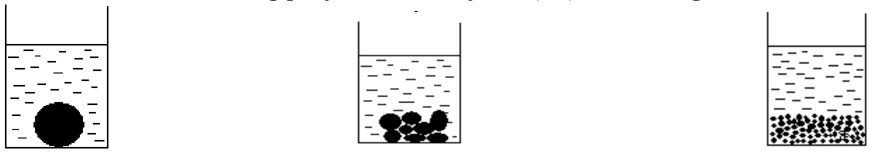
a) Reaksiyon hızı, moleküllerin birim zamandaki çarpışma hızıdır.
b) Reaksiyon hızı, bir reaksiyonun başlaması ve bitmesi arasında geçen süredir.
c) Reaksiyon hızı, birim zamanda çarpışan atom sayısıdır.
d) Reaksiyon hızı, reaksiyona girenlerin gösterdikleri değişimdir.
e) Reaksiyon hızı, birim zamanda girenlerin derişimindeki azalmadır.

17. Katalizör ile ilgili olarak aşağıdakilerden hangisi doğrudur?

a) Katalizör reaksiyona giren fakat reaksiyona etki etmeden çıkan ara maddedir.
b) Katalizör ileri tepkime hızını ve geri tepkime hızını düşüren maddedir.
c) Katalizör bir reaksiyon sırasında oluşan sonra tükenen maddedir..
d) Katalizör bir reaksiyonun aktivasyon enerjisini düşüren maddedir.
e) Katalizör bir reaksiyonun ΔH'ı düşüren yabancı maddedir.

18. Aşağıdaki kapların her birinde $Zn_{(k)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(k)} + H_{2(g)}$ tepkimesi gerçekleşmektedir.

1 g küre biciminde çinko | 1 g parçalar halinde çinko (Zn) | 1 g toz halinde çinko (Zn)



I. Kap	II. Kap	III. Kap
25 ^{0}C de 1M HCl çözeltisi	25 ^{0}C de 1M HCl çözeltisi	25 ^{0}C de 1M HCl çözeltisi

Şekilde verilen bilgilere göre, üç kapta gerçekleşen tepkimelerin hızları karşılaştırıldığında $V_{III}>V_{II}>V_I$ olarak belirlenmiştir.

Bunun nedeni aşağıdakilerden hangisinde doğru olarak verilmiştir?

a) Tanecik boyutu küçüldükçe temas yüzeyi arttığı için reaksiyon hızı artar.
b) Reaksiyona giren maddenin tanecik boyutu küçülünce hacmi küçülür, bu yüzden daha hızlı reaksiyon verir.
c) Toz halindeki madde daha çabuk erir bu yüzden reaksiyon hızı artar.
d) Tanecik boyutu büyük olan maddeler küçük olanlara göre daha yavaş hareket edeceğinden reaksiyon hızı azalır.
e) Tanecik boyutu büyük olan maddeler daha hızlı tepkime verir.

19. $2X_{(g)} + 3Y_{(g)} \rightarrow 2A_{(g)}$ reaksiyonu iki adımlı bir mekanizmaya sahiptir.

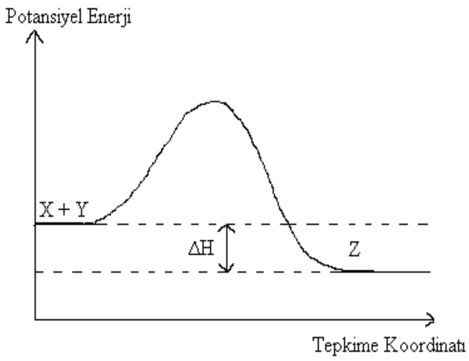
Mekanizmadaki hızlı adım $X_{(g)} + Y_{(g)} + 2Z_{(g)} \rightarrow 2A_{(g)}$ ise, reaksiyonun hız ifadesi aşağıdakilerden hangisidir?

a) Hız = k [X][Y]
b) Hız = k $[A]^2$
c) Hız = k $[X][Y][Z]^2$
d) Hız = k $[X]^2[Y]^3[Z]^2$
e) Hız = k $[X]\,[Y]^2$

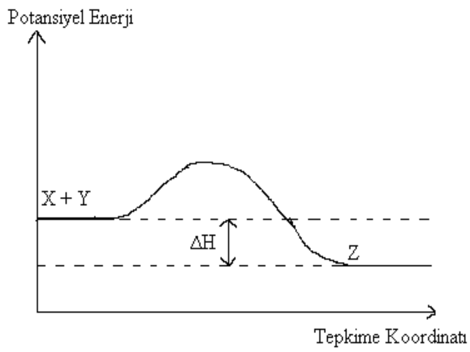
20. Derişimin reaksiyon hızına etkisi ile ilgili aşağıdakilerden hangisi doğrudur?

a) Derişimin artması etki yüzeyinin artmasını sağladığı için reaksiyon hızlanır.
b) Derişim artınca reaksiyona giren taneciklerin etkin çarpışma olasılığı arttığı için reaksiyon hızlanır.
c) Derişim artınca aktivasyon enerjisi azalır böylece aktivasyon enerjisini geçen tanecik sayısı arttığı için reaksiyon hızlanır.
d) Maddenin derişimi artınca kinetik enerjisi arttığı için reaksiyon hızı artar.
e) Derişim artınca yoğunluk artar böylece moleküller daha hızlı çarpıştığı için sıcaklık artar ve reaksiyon hızlanır.

21. Potansiyel enerji-tepkime koordinatı grafiği Şekil I de verilen $X_{(g)}$+ $Y_{(g)}$→$Z_{(g)}$ tepkimesine aşağıdaki işlemlerden hangisi uygulanırsa Şekil II deki grafik elde edilir?



Şekil I



Şekil II

a) Basıncı artırmak
b) Sıcaklığı azaltmak
c) Katalizör kullanmak
d) X + Y eklemek
e) Z eklemek

22. $2NO_{2(g)} + F_{2(g)} \rightarrow 2NO_2F_{(g)}$ reaksiyonun mekanizması aşağıdaki gibidir.

$NO_{2(g)} + F_{2(g)} \rightarrow NO_2F_{(g)} + F_{(g)}$ (yavaş)

$NO_{2(g)} + F_{(g)} \rightarrow NO_2F_{(g)}$ (hızlı)

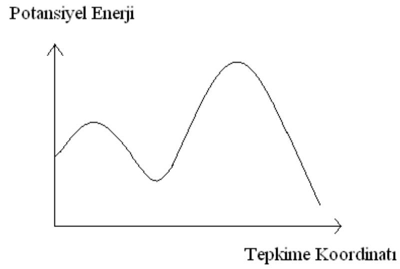
Buna göre, aşağıdakilerden hangisi <u>yanlıştır?</u>

a) F_2 derişimi reaksiyon hızını etkiler.
b) NO_2'nin derişimi 2 katına çıkarılırsa hız da iki katına çıkar.
c) Reaksiyondaki F katalizördür.
d) Reaksiyon 2.derecedendir.
e) Kabın hacmi yarıya düşürülürse reaksiyon hızı 4 kat artar.

23. Tek adımda gerçekleşen gaz fazındaki bir reaksiyonda reaksiyona giren maddelerden birinin derişiminin artması ile aşağıdakilerden hangisi gerçekleşir?

a) Taneciklerin kinetik enerjisi artar.
b) Aktivasyon enerjisi azalır.
c) Reaksiyon hızı değişmez.
d) Etkin çarpışma sayısı değişmez.
e) Reaksiyon hız sabiti değişmez.

24. Potansiyel enerji-tepkime koordinatı grafiği yanda verilen reaksiyon için aşağıdakilerden hangisi <u>yanlıştır?</u>



a) I. basamak reaksiyonun hızını belirleyen basamaktır.
b) Reaksiyon 2 basamaklı bir mekanizma ile gerçekleşmektedir.
c) II. basamağın aktivasyon enerjisi I. basamağınkinden daha fazladır.
d) I. basamak II. basamaktan daha hızlıdır.
e) Reaksiyon ekzotermiktir.

25. I. $A + B \rightarrow C$
II. $C + D \rightarrow E + F$
III. $F + G \rightarrow H + B$

Mekanizması yukarıdaki 3 adımdan oluşan reaksiyondaki ara ürün ve katalizör olan maddeler aşağıdakilerden hangisinde doğru olarak verilmiştir?

	Ara ürün	Katalizör
a)	C	B
b)	B	F
c)	F	H
d)	C ve F	B
e)	E ve F	C

Table C.1 Reaksiyon Hızı Kavram Testinin Yanıt Anahtarı

1-e	6-d	11-a	16-e	21-c
2-d	7-a	12-c	17-d	22-c
3-b	8-b	13-e	18-a	23-e
4-a	9-b	14-c	19-e	24-a
5-c	10-d	15-b	20-b	25-d

APPENDIX D

REAKSİYON HIZI BAŞARI TESTİ

Aşağıda "Reaksiyon Hızı" konusu ile ilgili 25 çoktan seçmeli sorudan oluşan bir başarı testi verilmiştir. Testteki her bir soru 5 seçenek içermektedir. Lütfen her bir soru için size en doğru gelen seçeneği işaretleyiniz. Başarılar.

1. Tek adımda gerçekleşen $X_{(g)} + 2Y_{(g)} \rightarrow 2Z_{(g)}$ reaksiyonunun 60^0C'de gerçekleştiği kabın hacmi yarıya indirilip sıcaklık 80^0C'ye çıkarıldığında reaksiyonun hızı 24 kat artmıştır.

Buna göre, reaksiyonun 80^0C'deki hız sabitinin 60^0C'deki hız sabitine oranı kaçtır?

a) 3 b) 4 c) 5 d) 6 e) 7

2. $N_2O_{4\,(g)} \rightarrow 2NO_{2\,(g)}$ reaksiyonunun gerçekleştiği 1 L'lik kapta 0,6 mol N_2O_4 ve 0,3 mol NO_2 gazı varken kaba 0,3 mol N_2O_4 ilave ediliyor ve sabit sıcaklıkta kabın hacmi 2 katına çıkarılıyor.

Bu durumda reaksiyon hızı kaç katına çıkar?

a) 3 b) 1,5 c) 0,75 d) 0,9 e) 0,50

3. $2NO_{(g)} + O_{2\,(g)} \rightarrow 2NO_{2\,(g)}$ reaksiyonunun hızına ait deney sonuçları aşağıdaki tabloda verilmiştir.

Deney No	[NO] (mol/L)	[O_2] (mol/L)	Reaksiyon Hızı (mol/L.sn)
1	0.01	0.01	$7x10^{-5}$
2	0.01	0.02	$14x10^{-5}$
3	0.02	0.02	$28x10^{-5}$

Buna göre reaksiyonun hız denklemi aşağıdakilerden hangisidir?

a) Hız = k [NO] $[O_2]^2$

b) Hız = k $[NO]^2$ [O_2]

c) Hız = k $[NO]^2$ $[O_2]^4$

d) Hız = k $[NO]^4$ $[O_2]^4$

e) Hız = k [NO] [O_2]

4. **$A_{(g)} + B_{(k)} + C_{(g)} \rightarrow D_{(k)} + E_{(g)}$ tepkimesi için aşağıdaki etkilerden hangisi tepkimenin hızını artırmaz?**

a) Sabit hacimde 3 mol A eklemek

b) Sabit hacimde 2 mol B eklemek

c) Sabit hacim ve sıcaklıkta B'yi toz haline getirmek

d) Sıcaklığı 25 ^{0}C'den 50 ^{0}C'ye yükseltmek

e) Kabın hacmini 2 L'den 1 L'ye düşürmek

5. $A_{(suda)} + 2B_{(suda)} \rightarrow 3C_{(suda)}$ reaksiyonunun hız denklemi Hız = k [A][B]'dir. A ve B maddelerinin derişimleri 0.02 M alındığında birim zamanda C'nin derişimindeki artma 1,2 M oluyor.

Buna göre, A'nın derişimi 0,03 M, B'nin derişimi 0,02 M olduğunda birim zamanda C'nin derişimindeki artma kaç M olur?

a) 18 b)8 c) 2,8 d) 1,8 e) 0,8

6. $2A_{(g)} + 2B_{(g)} + 2C_{(g)} \rightarrow 2X_{(g)} + 3Y_{(g)}$ reaksiyonundaki girenlerin farklı derişimleri ile aynı sıcaklıkta yapılan deneylerle reaksiyon hızları belirlenmiştir. Bu deneylerin sonuçları aşağıdaki tabloda verilmiştir.

Deney No	[A](mol/L)	[B](mol/L)	[C](mol/L)	Reaksiyon Hızı(mol/L.sn)
1	0.2	0.03	0,4	$1,6x10^{-3}$
2	0.4	0.02	0,4	$3,2x10^{-3}$
3	0.2	0.01	0,4	$1,6x10^{-3}$
4	0,2	0,03	0,8	$6,4x10^{-3}$

Buna göre reaksiyonun hız sabitinin değeri kaçtır?

a) 0,5 b) 0,05 c)0,005 d) 0,025 e) 0,25

7. Aşağıdaki reaksiyonlardan hangisinin hızı sabit sıcaklık ve hacimde basınç değişimi ile ölçülebilir?

a) $CO_{2(g)} + NO_{(g)} \rightarrow CO_{(g)} + NO_{2(g)}$

b) $Ca^{+2}_{(suda)} + 2Cl^{-}_{(suda)} \rightarrow CaCl_{2(k)}$

c) $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

d) $H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

e) $CO_{2(g)} + H_{2(g)} \rightarrow CO_{(g)} + H_2O_{(g)}$

8. $3ClO^{-}_{(suda)} \rightarrow 2Cl^{-}_{(suda)} + ClO_3{}^{-}_{(suda)}$ reaksiyonunun mekanizması aşağıdaki gibidir.

$2ClO^{-}_{(suda)} \rightarrow Cl^{-}_{(suda)} + ClO_2{}^{-}_{(suda)}$ (yavaş)

$ClO_2{}^{-}_{(suda)} + ClO^{-}_{(suda)} \rightarrow Cl^{-}_{(suda)} + ClO_3{}^{-}_{(suda)}$ (hızlı)

Buna göre, ClO_2^- derişimi 3 kat artırılırsa reaksiyon hızı nasıl değişir?

a) 9 kat artar.

b) 9 kat azalır.

c) 3 kat artar.

d) 3 kat azalır.

e) Değişmez.

9. Hız eşitliği Hız = k $[A_2][B]^2$ olan bir reaksiyon için,

I. Reaksiyonun yavaş adımında girenler $A_2 + 2B$'dir.
II. A_2 derişimi 3 katına çıkarılırsa reaksiyon hızı 9 katına çıkar.
III. Reaksiyonun gerçekleştiği kabın hacmi 3 kat azaltılırsa tepkime hızı da 3 kat azalır.

yargılarından hangisi ya da hangileri doğrudur?

a) Yalnız I b) Yalnız II c) I ve II d) II ve III e) I, II, III

10. $2A_{2(g)} + 6B_{2(g)} \rightarrow 4AB_{3(g)}$ reaksiyonunun basamakları aşağıdaki gibidir.

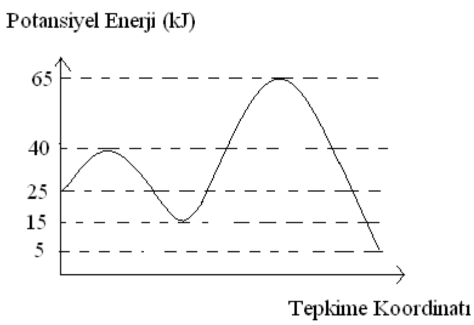
I. $A_{2(g)} \rightarrow 2A_{(g)}$ RH = $2x10^{-2}$
II. $2A_{(g)} + 4B_{2(g)} \rightarrow A_2B_{8(g)}$ RH = $4x10^{-2}$
III. $A_{2(g)} + 2B_{2(g)} + A_2B_{8(g)} \rightarrow 4AB_{3(g)}$ RH = $3x10^{-1}$

Buna göre, bu reaksiyonun hız ifadesi aşağıdakilerden hangisidir?

a) RH = k $[A_2]^2 [B_2]^6$ b) RH = k $[A]^2 [B_2]^4$ c) RH = k $[A_2] [B_2]^2[A_2B_8]$
d) RH = k $[A_2]$ e) RH = k $[AB_3]^4$

11. Bir reaksiyonun potansiyel enerji-tepkime koordinatı grafiği yandaki gibidir.

Buna göre, aşağıdakilerden hangisi <u>yanlıştır?</u>



a) Reaksiyon iki adımlı bir mekanizmaya sahiptir.
b) İkinci adım birinci adımdan daha yavaştır.
c) Hızlı adımın aktivasyon enerjisi 15 kJ'dür.
d) Birinci adımın reaksiyon ısısı -10 kJ'dür.
e) Reaksiyonun hızını belirleyen adımın aktivasyon enerjisi 40 kJ'dür.

12. $2H_2O_{2(suda)} \rightarrow 2H_2O_{(s)} + O_{2(g)}$ reaksiyonu aşağıdaki basamaklardan oluşmaktadır.

I. $H_2O_{2(suda)} + I^-_{(suda)} \rightarrow H_2O_{(s)} + IO^-_{(suda)}$ (yavaş)

II. $H_2O_{2(suda)} + IO^-_{(suda)} \rightarrow H_2O_{(s)} + O_{2(g)} + I^-_{(suda)}$ (hızlı)

Buna göre, aşağıdakilerden hangisi yanlıştır?

a) Reaksiyonun hız eşitliği, Hız = k $[H_2O_2]$ $[I^-]$'dir.
b) Reaksiyon 2. derecedendir.
c) I^- ara ürün, IO^- ise katalizördür.
d) H_2O_2 derişimi 3 katına çıkarılırsa reaksiyon hızı da 3 katına çıkar.
e) IO^- derişimi reaksiyon hızını etkilemez.

13. I. $X_{(k)} + O_{2(g)} \rightarrow XO_{2(g)}$

II. $XO_{2(g)} + YO_{2(g)} \rightarrow XO_{3(g)} + YO_{(g)}$

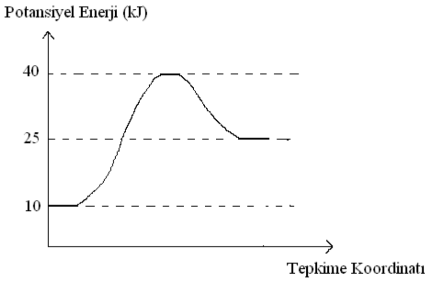
III. $XO_{3(g)} + H_2O_{(s)} \rightarrow H_2XO_{4(s)}$

H_2XO_4, yukarıdaki 3 basamaklı bir mekanizma sonucu 24 dakikada oluşmaktadır.1. basamağı 2. basamağından 3 kat hızlı olan mekanizmada 3. basamak 4 dakikada gerçekleşmektedir.

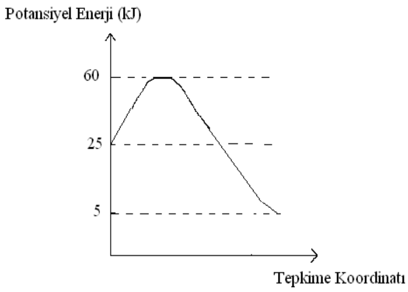
Buna göre net reaksiyonun hız bağıntısı aşağıdakilerden hangisidir?

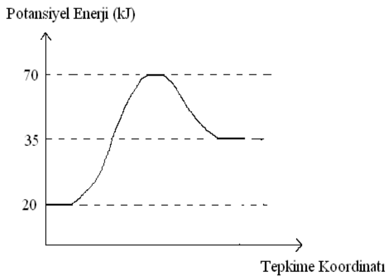
a) RH = k $[XO_2]$ $[YO_2]$
b) RH = k $[O_2]$
c) RH = k $[H_2XO_4]$
d) RH = k $[XO_3]$ $[H_2O]$
e) RH = k $[XO_3]$

14.



(I)





(II) (III)

Potansiyel enerji-tepkime koordinatı grafikleri yukarıdaki gibi olan 3 farklı reaksiyon aynı koşullarda ve aynı anda başlatılıyor.

Bu reaksiyonların hızları arasındaki ilişki aşağıdakilerden hangisinde doğru olarak verilmiştir?

a) $RH_{III}>RH_{II}>RH_{I}$

b) $RH_{I}>RH_{II}>RH_{III}$

c) $RH_{II}>RH_{III}>RH_{I}$

d) $RH_{I}=RH_{III}>RH_{II}$

e) $RH_{I}=RH_{II}=RH_{III}$

15. 25 ^{0}C'de ve 1 L'lik kapta tek adımda gerçekleşen $2X_{(g)} + Y_{2(g)} \rightarrow X_2Y_{2(g)}$ reaksiyonunun aktivasyon enerjisi 60 kJ ve reaksiyon hız sabiti $2x10^{-2}$'dir.

Buna göre aşağıdakilerden hangisi doğru olabilir?

a) Katalizör kullanıldığında aktivasyon enerjisi 70 kJ olur.

b) Hacim 2 L'ye çıkarılınca reaksiyon hızı 2 kat artar.

c) 2 mol X gazı eklenince etkin çarpışma sayısı azalır.

d) Sıcaklık 40 ^{0}C'ye çıkarılınca aktivasyon enerjisi değişmez.

e) 3 mol Y_2 gazı eklenince reaksiyon hız sabiti de 3 katına çıkar.

Table D.1 Reaksiyon Hızı Başarı Testinin Yanıt Anahtarı

1-a	6-b	11-e
2-c	7-c	12-c
3-e	8-e	13-a
4-b	9-a	14-b
5-d	10-d	15-d

APPENDIX E

KİMYA DERSİ TUTUM ÖLÇEĞİ

Bu ölçekte, kimya dersine ilişkin tutum cümleleri ile her cümlenin karşısında "Tamamen Katılıyorum", "Katılmıyorum", " Kararsızım", "Katılmıyorum" ve "Tamamen Katılmıyorum" olmak üzere beş seçenek verilmiştir. Her cümleyi dikkatle okuduktan sonra kendinize uygun seçeneği işaretleyiniz.

	Tamamen Katılıyorum	Katılıyorum	Kararsızım	Katılmıyorum	Hiç Katılmıyorum
1. Kimya çok sevdiğim bir alandır.					
2. Kimya ile ilgili kitapları okumaktan hoşlanırım.					
3. Kimyanın günlük yaşantıda çok önemli yeri yoktur.					
4. Kimya ile ilgili ders problemlerini çözmekten hoşlanırım.					
5. Kimya konularıyla ilgili daha çok şey öğrenmek isterim.					
6. Kimya dersine girerken sıkıntı duyarım.					
7. Kimya derslerine zevkle girerim.					
8. Kimya derslerine ayrılan ders saatinin daha fazla olmasını isterim.					
9. Kimya dersini çalışırken canım sıkılır.					
10. Kimya konularını ilgilendiren günlük olaylar hakkında daha fazla bilgi edinmek isterim.					
11. Düşünce sistemimizi geliştirmede kimya öğrenimi önemlidir.					
12. Kimya, çevremizdeki doğal olayların daha iyi anlaşılmasında önemlidir.					
13. Dersler içinde Kimya dersi sevimsiz gelir.					
14. Kimya konularıyla ilgili tartışmaya katılmak bana cazip gelmez.					
15. Çalışma zamanımın önemli bir kısmını kimya dersine ayırmak isterim.					

APPENDIX F

BİLİMSEL İŞLEM BECERİ TESTİ

Bu test, özellikle Fen ve Matematik derslerinizde ve ilerde üniversite sınavlarında karşınıza çıkabilecek karmaşık gibi görünen problemleri analiz edebilme kabiliyetinizi ortaya çıkarabilmesi açısından çok faydalıdır. Bu test içinde, problemdeki değişkenleri tanımlayabilme, hipotez kurma ve tanımlama, işlemsel açıklamalar getirebilme, problemin çözümü için gerekli incelemelerin tasarlanması, grafik çizme ve verileri yorumlayabilme kabiliyetlerini ölçebilen sorular bulunmaktadır. Her soruyu okuduktan sonra kendinizce uygun seçeneği işaretleyiniz.

1. Bir basketbol antrenörü, oyuncuların güçsüz olmasından dolayı maçları kaybettiklerini düşünmektedir. Güçlerini etkileyen faktörleri araştırmaya karar verir. Antrenör, oyuncuların gücünü etkileyip etkilemediğini ölçmek için aşağıdaki değişkenlerden hangisini incelemelidir?

a. Her oyuncunun almış olduğu günlük vitamin miktarını.

b. Günlük ağırlık kaldırma çalışmalarının miktarını.

c. Günlük antrenman süresini.

d. Yukarıdakilerin hepsini.

2. Arabaların verimliliğini inceleyen bir araştırma yapılmaktadır. Sınanan hipotez, benzine katılan bir katkı maddesinin arabaların verimliliğini artırdığı yolundadır. Aynı tip beş arabaya aynı miktarda benzin fakat farklı miktarlarda katkı maddesi konur. Arabalar benzinleri bitinceye kadar aynı yol üzerinde giderler. Daha sonra her arabanın aldığı mesafe kaydedilir. Bu çalışmada arabaların verimliliği nasıl ölçülür?

a. Arabaların benzinleri bitinceye kadar geçen süre ile.

b. Her arabanın gittiği mesafe ile.

c. Kullanılan benzin miktarı ile.

d. Kullanılan katkı maddesinin miktarı ile.

3. Bir araba üreticisi daha ekonomik arabalar yapmak istemektedir. Araştırmacılar arabanın litre başına alabileceği mesafeyi etkileyebilecek değişkenleri araştırmaktadırlar. Aşağıdaki değişkenlerden hangisi arabanın litre başına alabileceği mesafeyi etkileyebilir?

a. Arabanın ağırlığı.

b. Motorun hacmi.

c. Arabanın rengi

d. a ve b.

4. Ali Bey, evini ısıtmak için komşularından daha çok para ödenmesinin sebeplerini merak etmektedir. Isınma giderlerini etkileyen faktörleri araştırmak için bir hipotez kurar. Aşağıdakilerden hangisi bu araştırmada sınanmaya uygun bir hipotez değildir?

a. Evin çevresindeki ağaç sayısı ne kadar az ise ısınma gideri o kadar fazladır.

b. Evde ne kadar çok pencere ve kapı varsa, ısınma gideri de o kadar fazla olur.

c. Büyük evlerin ısınma giderleri fazladır.

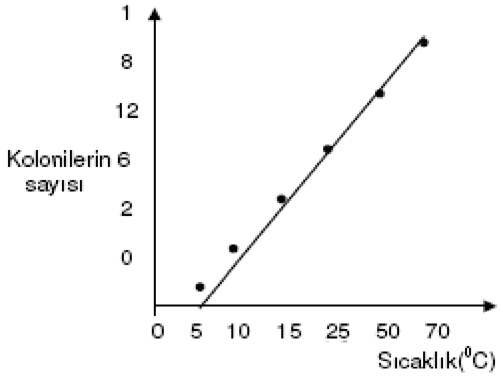
d. Isınma giderleri arttıkça ailenin daha ucuza ısınma yolları araması gerekir.

5. Fen sınıfından bir öğrenci sıcaklığın bakterilerin gelişmesi üzerindeki etkilerini araştırmaktadır. Yaptığı deney sonucunda, öğrenci aşağıdaki verileri elde etmiştir:

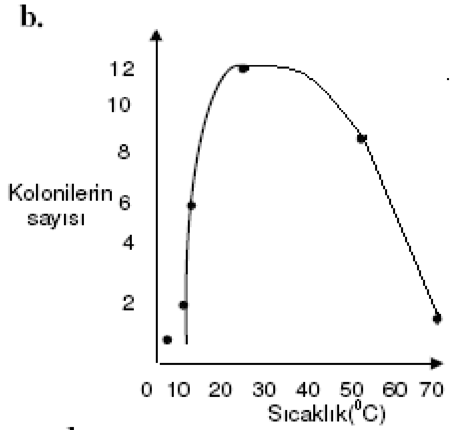
Deney odasının sıcaklığı (^{0}C)	Bakteri kolonilerinin sayısı
5	0
10	2
15	6
25	12
50	8
70	1

Aşağıdaki grafiklerden hangisi bu verileri doğru olarak göstermektedir?

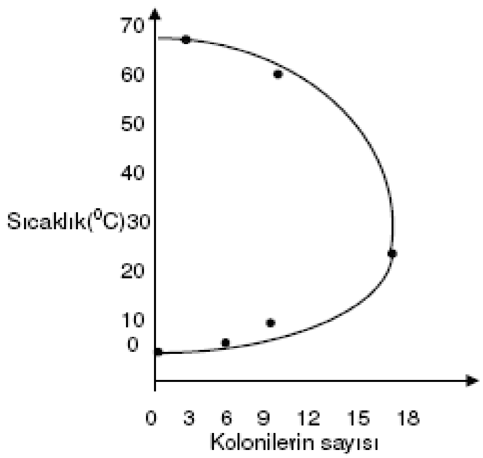
a.



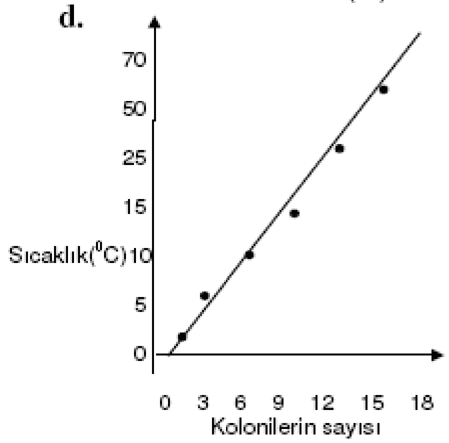
b.



c.



d.



6. Bir polis şefi, arabaların hızının azaltılması ile uğraşmaktadır. Arabaların hızını etkileyebilecek bazı faktörler olduğunu düşünmektedir. Sürücülerin ne kadar hızlı araba kullandıklarını aşağıdaki hipotezlerin hangisiyle sınayabilir?

a. Daha genç sürücülerin daha hızlı araba kullanma olasılığı yüksektir.

b. Kaza yapan arabalar ne kadar büyükse, içindeki insanların yaralanma olasılığı o kadar azdır.

c. Yollarda ne kadar çok polis ekibi olursa, kaza sayısı o kadar az olur.

d. Arabalar eskidikçe kaza yapma olasılıkları artar.

7. Bir fen sınıfında, tekerlek yüzeyi genişliğinin tekerleğin daha kolay yuvarlanması üzerine etkisi araştırılmaktadır. Bir oyuncak arabaya geniş yüzeyli tekerlekler takılır, önce bir rampadan (eğik düzlem) aşağı bırakılır ve daha sonra düz bir zemin üzerinde gitmesi sağlanır. Deney, aynı arabaya daha dar yüzeyli tekerlekler takılarak tekrarlanır. Hangi tip tekerleğin daha kolay yuvarlandığı nasıl ölçülür?

a. Her deneyde arabanın gittiği toplam mesafe ölçülür.

b. Rampanın (eğik düzlem) eğim açısı ölçülür.

c. Her iki deneyde kullanılan tekerlek tiplerinin yüzey genişlikleri ölçülür.

d. Her iki deneyin sonunda arabanın ağırlıkları ölçülür.

8. Bir çiftçi daha çok mısır üretebilmenin yollarını aramaktadır. Mısırların miktarını etkileyen faktörleri araştırmayı tasarlar. Bu amaçla aşağıdaki hipotezlerden hangisini sınayabilir?

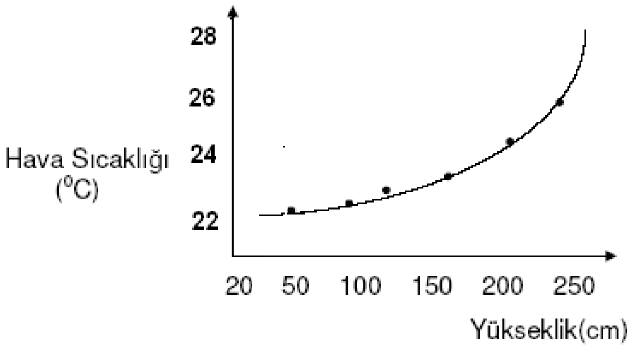
a. Tarlaya ne kadar çok gübre atılırsa, o kadar çok mısır elde edilir.

b. Ne kadar çok mısır elde edilirse, kar o kadar fazla olur.

c. Yağmur ne kadar çok yağarsa , gübrenin etkisi o kadar çok olur.

d. Mısır üretimi arttıkça, üretim maliyeti de artar.

9. Bir odanın tabandan itibaren değişik yüzeylerdeki sıcaklıklarıylala ilgili bir çalışma yapılmış ve elde edilen veriler aşağıdaki grafikte gösterilmiştir. Değişkenler arasındaki ilişki nedir?



a. Yükseklik arttıkça sıcaklık azalır.

b. Yükseklik arttıkça sıcaklık artar.

c. Sıcaklık arttıkça yükseklik azalır.

d. Yükseklik ile sıcaklık artışı arasında bir ilişki yoktur.

10. Ahmet, basketbol topunun içindeki hava arttıkça, topun daha yükseğe sıçrayacağını düşünmektedir. Bu hipotezi araştırmak için, birkaç basketbol topu alır ve içlerine farklı miktarda hava pompalar. Ahmet hipotezini nasıl sınamalıdır?

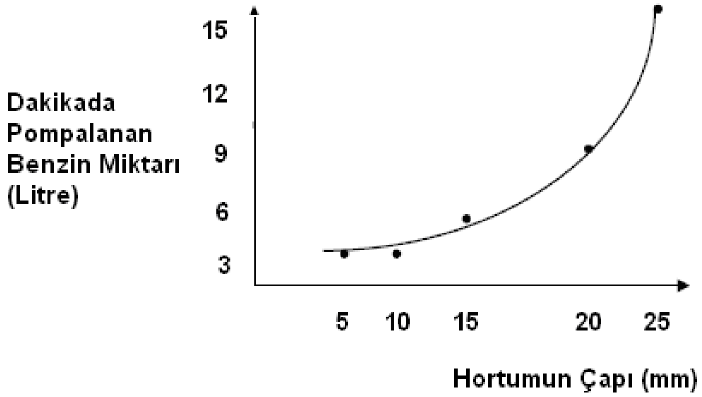
a. Topları aynı yükseklikten fakat değişik hızlarla yere vurur.

b. İçlerinde farlı miktarlarda hava olan topları, aynı yükseklikten yere bırakır.

c. İçlerinde aynı miktarlarda hava olan topları, zeminle farklı açılardan yere vurur.

d. İçlerinde aynı miktarlarda hava olan topları, farklı yüksekliklerden yere bırakır.

11. Bir tankerden benzin almak için farklı genişlikte 5 hortum kullanılmaktadır. Her hortum için aynı pompa kullanılır. Yapılan çalışma sonunda elde edilen bulgular aşağıdaki grafikte gösterilmiştir.



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?

a. Hortumun çapı genişledikçe dakikada pompalanan benzin miktarı da artar.

b. Dakikada pompalanan benzin miktarı arttıkça, daha fazla zaman gerekir.

c. Hortumun çapı küçüldükçe dakikada pompalanan benzin miktarı da artar.

d. Pompalanan benzin miktarı azaldıkça, hortumun çapı genişler.

Önce aşağıdaki açıklamayı okuyunuz ve daha sonra 12, 13, 14 ve 15 inci soruları açıklama kısmından sonra verilen paragrafı okuyarak cevaplayınız.

Açıklama: Bir araştırmada, bağımlı değişken birtakım faktörlere bağımlı olarak gelişim gösteren değişkendir. Bağımsız değişkenler ise bağımlı değişkene etki eden faktörlerdir. Örneğin, araştırmanın amacına göre kimya başarısı bağımlı bir değişken olarak alınabilir ve ona etki edebilecek faktör veya faktörler de bağımsız değişkenler olurlar.

Ayşe, güneşin karaları ve denizleri aynı derecede ısıtıp ısıtmadığını merak etmektedir. Bir araştırma yapmaya karar verir ve aynı büyüklükte iki kova alır. Bunlardan birini toprakla, diğerini de su ile doldurur ve aynı miktarda güneş ısısı alacak şekilde bir yere koyar. 8.00 - 18.00 saatleri arasında, her saat başı sıcaklıklarını ölçer.

12. Araştırmada aşağıdaki hipotezlerden hangisi sınanmıştır?

a. Toprak ve su ne kadar çok güneş ışığı alırlarsa, o kadar ısınırlar.

b. Toprak ve su güneş altında ne kadar fazla kalırlarsa, o kadar çok ısınırlar.

c. Güneş farklı maddeleri farklı derecelerde ısıtır.

d. Günün farklı saatlerinde güneşin ısısı da farklı olur.

13. Araştırmada aşağıdaki değişkenlerden hangisi kontrol edilmiştir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

14. Araştırmada bağımlı değişken hangisidir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

15. Araştırmada bağımsız değişken hangisidir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

16. Can, yedi ayrı bahçedeki çimenleri biçmektedir. Çim biçme makinesiyle her hafta bir bahçedeki çimenleri biçer. Çimenlerin boyu bahçelere göre farklı olup bazılarında uzun bazılarında kısadır. Çimenlerin boyları ile ilgili hipotezler kurmaya başlar. Aşağıdakilerden hangisi sınanmaya uygun bir hipotezdir?

a. Hava sıcakken çim biçmek zordur.

b. Bahçeye atılan gürenin miktarı önemlidir.

c. Daha çok sulanan bahçedeki çimenler daha uzun olur.

d. Bahçe ne kadar engebeliyse çimenleri kesmekte o kadar zor olur.

17, 18, 19 ve 20 inci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Murat, suyun sıcaklığının, su içinde çözünebilecek şeker miktarını etkileyip etkilemediğini araştırmak ister. Birbirinin aynı dört bardağın her birine 50 şer mililitre su koyar. Bardaklardan birisine 0 ^{0}C de, diğerine de sırayla 50 ^{0}C, 75 ^{0}C ve 95 ^{0}C sıcaklıkta su koyar. Daha sonra her bir bardağa çözünebileceği kadar şeker koyar ve karıştırır.

17. Bu araştırmada sınanan hipotez hangisidir?

a. Şeker ne kadar çok suda karıştırılırsa o kadar çok çözünür.

b. Ne kadar çok şeker çözünürse, su o kadar tatlı olur.

c. Sıcaklık ne kadar yüksek olursa, çözünen şekerin miktarı o kadar fazla olur.

d. Kullanılan suyun miktarı arttıkça sıcaklığı da artar.

18. Bu araştırmada kontrol edilebilen değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

19. Araştırmanın bağımlı değişkeni hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

20. Araştırmadaki bağımsız değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

21. Bir bahçıvan domates üretimini artırmak istemektedir. Değişik birkaç alana domates tohumu eker. Hipotezi, tohumlar ne kadar çok sulanırsa, o kadar çabuk filizleneceğidir. Bu hipotezi nasıl sınar?

a. Farklı miktarlarda sulanan tohumların kaç günde filizleneceğine bakar.

b. Her sulamadan bir gün sonra domates bitkisinin boyunu ölçer.

c. Farklı alanlardaki bitkilere verilen su miktarını ölçer.

d. Her alana ektiği tohum sayısına bakar.

22. Bir bahçıvan tarlasındaki kabaklarda yaprak bitleri görür. Bu bitleri yok etmek gereklidir. Kardeşi "Kling" adlı tozun en iyi böcek ilacı olduğunu söyler. Tarım uzmanları ise "Acar" adlı spreyin daha etkili olduğunu söylemektedir. Bahçıvan altı tane kabak bitkisi seçer. Üç tanesini tozla, üç tanesini de spreyle ilaçlar. Bir hafta sonra her bitkinin üzerinde kalan canlı bitleri sayar. Bu çalışmada böcek ilaçlarının etkinliği nasıl ölçülür?

a. Kullanılan toz yada spreyin miktarı ölçülür.

b. Toz yada spreyle ilaçlandıktan sonra bitkilerin durumları tespit edilir.

c. Her fidede oluşan kabağın ağırlığı ölçülür.

d. Bitkilerin üzerinde kalan bitler sayılır.

23. Ebru, bir alevin belli bir zaman süresi içinde meydana getireceği ısı enerjisi miktarını ölçmek ister. Bir kabın içine bir litre soğuk su koyar ve 10 dakika süreyle ısıtır. Ebru, alevin meydana getirdiği ısı enerjisini nasıl ölçer?

a. 10 dakika sonra suyun sıcaklığında meydana gelen değişmeyi kaydeder.

b. 10 dakika sonra suyun hacminde meydana gelen değişmeyi ölçer.

c. 10 dakika sonra alevin sıcaklığını ölçer.

d. Bir litre suyun kaynaması için geçen zamanı ölçer.

24. Ahmet, buz parçacıklarının erime süresini etkileyen faktörleri merak etmektedir. Buz parçalarının büyüklüğü, odanın sıcaklığı ve buz parçalarının şekli gibi faktörlerin erime süresini etkileyebileceğini düşünür. Daha sonra şu hipotezi sınamaya karar verir: Buz parçalarının şekli erime süresini etkiler.Ahmet bu hipotezi sınamak için aşağıdaki deney tasarımlarının hangisini uygulamalıdır?

a. Her biri farklı şekil ve ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

b. Her biri aynı şekilde fakat farklı ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

c. Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

d. Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

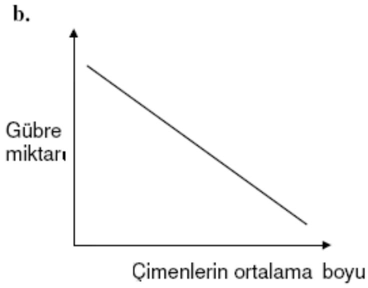
25. Bir araştırmacı yeni bir gübreyi denemektedir. Çalışmalarını aynı büyüklükte beş tarlada yapar. Her tarlaya yeni gübresinden değişik miktarlarda karıştırır. Bir ay sonra, her tarlada yetişen çimenin ortalama boyunu ölçer. Ölçüm sonuçları aşağıdaki tabloda verilmiştir.

Gübre miktarı (kg)	Çimenlerin ortalama boyu (cm)
10	7
30	10
50	12
80	14
100	12

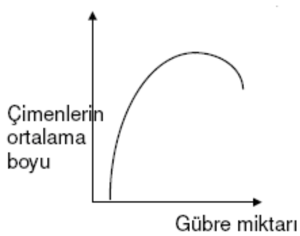
Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

a.

b.



c.



d.

26. Bir biyolog şu hipotezi test etmek ister: Farelere ne kadar çok vitamin verilirse o kadar hızlı büyürler. Biyolog farelerin büyüme hızını nasıl ölçebilir?

a. Farelerin hızını ölçer.

b. Farelerin, günlük uyumadan durabildikleri süreyi ölçer.

c. Her gün fareleri tartar.

d. Her gün farelerin yiyeceği vitaminleri tartar.

27. Öğrenciler, şekerin suda çözünme süresini etkileyebilecek değişkenleri düşünmektedirler. Suyun sıcaklığını, şekerin ve suyun miktarlarını değişken olarak saptarlar. Öğrenciler, şekerin suda çözünme süresini aşağıdaki hipotezlerden hangisiyle sınayabilir?

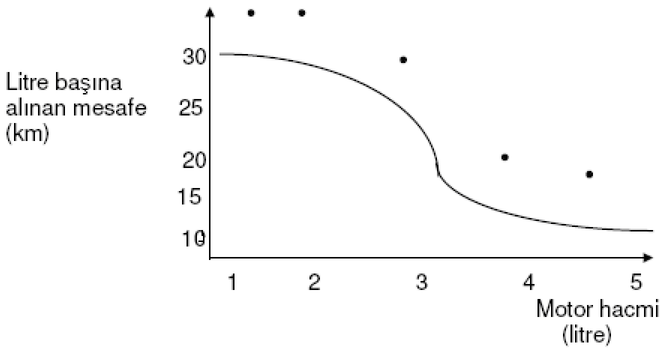
a. Daha fazla şekeri çözmek için daha fazla su gereklidir.

b. Su soğudukça, şekeri çözebilmek için daha fazla karıştırmak gerekir.

c. Su ne kadar sıcaksa, o kadar çok şeker çözünecektir.

d. Su ısındıkça şeker daha uzun sürede çözünür.

28. Bir araştırma grubu, değişik hacimli motorları olan arabaların randımanlarını ölçer. Elde edilen sonuçların grafiği aşağıdaki gibidir:



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi gösterir?

a. Motor ne kadar büyükse, bir litre benzinle gidilen mesafe de o kadar uzun olur.

b. Bir litre benzinle gidilen mesafe ne kadar az olursa, arabanın motoru o kadar küçük demektir.

c. Motor küçüldükçe, arabanın bir litre benzinle gidilen mesafe artar.

d. Bir litre benzinle gidilen mesafe ne kadar uzun olursa, arabanın motoru o kadar büyük demektir.

29, 30, 31 ve 32 inci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Toprağa karıştırılan yaprakların domates üretimine etkisi araştırılmaktadır. Araştırmada dört büyük saksıya aynı miktarda ve tipte toprak konulmuştur. Fakat birinci saksıdaki toprağa 15 kg., ikinciye 10 kg., üçüncüye ise 5 kg. çürümüş yaprak karıştırılmıştır. Dördüncü saksıdaki toprağa ise hiç çürümüş yaprak karıştırılmamıştır.Daha sonra bu saksılara domates ekilmiştir. Bütün saksılar güneşe konmuş ve aynı miktarda sulanmıştır. Her saksıdan elde edilen domates tartılmış ve kaydedilmiştir.

29. Bu araştırmada sınanan hipotez hangisidir?

a. Bitkiler güneşten ne kadar çok ışık alırlarsa, o kadar fazla domates verirler.

b. Saksılar ne kadar büyük olursa, karıştırılan yaprak miktarı o kadar fazla olur.

c. Saksılar ne kadar çok sulanırsa, içlerindeki yapraklar o kadar çabuk çürür.

d. Toprağa ne kadar çok çürük yaprak karıştırılırsa, o kadar fazla domates elde edilir.

30. Bu araştırmada kontrol edilen değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki toprak miktarı.

d. Çürümüş yaprak karıştırılan saksı sayısı.

31. Araştırmadaki bağımlı değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki toprak miktarı.

d. Çürümüş yaprak karıştırılan saksı sayısı.

32. Araştırmadaki bağımsız değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki toprak miktarı.

d. Çürümüş yaprak karıştırılan saksı sayısı.

33. Bir öğrenci mıknatısların kaldırma yeteneklerini araştırmaktadır. Çeşitli boylarda ve şekillerde birkaç mıknatıs alır ve her mıknatısın çektiği demir tozlarını tartar. Bu çalışmada mıknatısın kaldırma yeteneği nasıl tanımlanır?

a. Kullanılan mıknatısın büyüklüğü ile.

b. Demir tozlarını çeken mıknatısın ağırlığı ile.

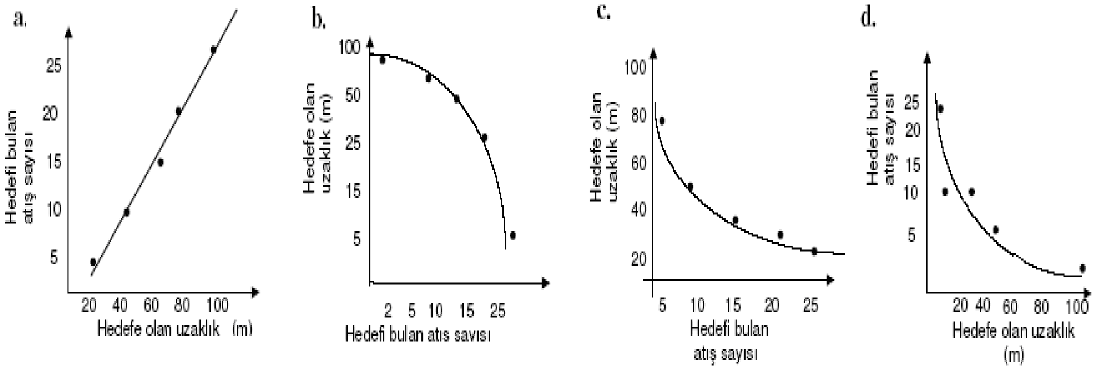
c. Kullanılan mıknatısın şekli ile.

d. Çekilen demir tozlarının ağırlığı ile.

34. Bir hedefe çeşitli mesafelerden 25 er atış yapılır. Her mesafeden yapılan 25 atıştan hedefe isabet edenler aşağıdaki tabloda gösterilmiştir.

Mesafe(m)	Hedefe vuran atış sayısı
5	25
15	10
25	10
50	5
100	2

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?



35. Sibel, akvaryumdaki balıkların bazen çok hareketli bazen ise durgun olduklarını gözler. Balıkların hareketliliğini etkileyen faktörleri merak eder. Balıkların hareketliliğini etkileyen faktörleri hangi hipotezle sınayabilir?

a. Balıklara ne kadar çok yem verilirse, o kadar çok yeme ihtiyaçları vardır.

b. Balıklar ne kadar hareketli olursa o kadar çok yeme ihtiyaçları vardır.

c. Su da ne kadar çok oksijen varsa, balıklar o kadar iri olur.

d. Akvaryum ne kadar çok ışık alırsa, balıklar o kadar hareketli olur.

36. Murat Bey'in evinde birçok elektrikli alet vardır. Fazla gelen elektrik faturaları dikkatini çeker. Kullanılan elektrik miktarını etkileyen faktörleri araştırmaya karar verir. Aşağıdaki değişkenlerden hangisi kullanılan elektrik enerjisi miktarını etkileyebilir?

a. TV nin açık kaldığı süre.

b. Elektrik sayacının yeri.

c. Çamaşır makinasını kullanma sıklığı.

d. a ve c.

Tablo F.1 Bilimsel İşlem Beceri Testinin Yanıt Anahtarı

1-d	10-b	19-a	28-c
2-b	11-a	20-d	29-d
3-d	12-c	21-a	30-c
4-d	13-d	22-d	31-a
5-b	14-b	23-a	32-b
6-a	15-c	24-c	33-d
7-a	16-c	25-c	34-d
8-a	17-c	26-c	35-d
9-b	18-b	27-d	36-d

APPENDIX G

OBSERVATION CHECKLIST

		Yes	Partially	No
1.	Does the teacher ask questions to the students to enhance dissatisfaction with their existing conceptions?			
2.	Does the teacher ask questions in order to determine students' misconceptions related to the subject?			
3.	Does the teacher make students be aware of their misconceptions?			
4.	Do students participate in classroom discourse during the instruction?			
5.	Does the teacher explain the concepts after students' dissatisfaction with their misconceptions?			
6.	Does the teacher consider students' misconceptions while explaining the concepts?			
7.	Does the teacher perform appropriate demonstration while explaining the concepts?			
8.	During demonstrations, does the teacher enhance all students to be able to see the demonstration?			
9.	Is there a discussion part both during the demonstration and after the demonstration?			
10.	Do students participate in the discussion related to demonstration?			
11.	Does the teacher solve quantitative questions related to the concepts?			
12.	Does the teacher give daily life examples in order to ensure plausibility of the concepts for the students?			
13.	Does the teacher summarize the topic?			
14.	Does the teacher give homework to the students?			
15.	Is there interaction between student and teacher, and between student and student?			

APPENDIX H

A SAMPLE LESSON PLAN ON CONCEPTUAL CHANGE BASED INSTRUCTION ABOUT THE EFFECT OF CONCENTRATION ON RATE OF REACTION

Introduction

The teacher will begin the lesson with the review of the previous lesson by asking some questions about rate of reaction to the students.

Teacher: As you remember, in the previous lesson we discussed about collision theory and activation energy. What can you say about these concepts? What is collision theory, what does it explain? What is activation energy?

The students will most probably answer these questions by expressing their ideas about collision theory and activation energy. After some students' answers, the teacher will summarize these concepts.

Teacher: Collision theory is a theory assuming that, for reaction to occur, reactant molecules must collide with energy greater than some minimum value and with the proper orientation. The minimum energy of the collision required for two molecules to react is called the activation energy.

Teacher: In this lesson, you will learn the effect of concentration on the rate of a reaction.

Dissatisfaction

The teacher starts the lesson by asking questions to students in order to activate their prior knowledge and misconceptions related to the effect of concentration on rate of reaction.

Teacher: Will rate of a reaction change if we increase the concentration of one of the reactants in the reaction?

Students may reply this question as “rate of reaction will not change” or “rate of reaction will decrease”. These answers indicate that they have misconceptions about the effect of concentration on rate of reaction. After that, the teacher will ask students the justification for the answers.

Teacher: Why will not rate of reaction change? Why will rate of reaction decrease?

Students may say that “rate of a reaction is independent of the reactants' concentration therefore rate of reaction will not change” or “increase in concentration of reactants decreases the number of effective collisions; therefore, rate of reaction decreases”. Even when some students say that rate of reaction will increase; they may still have misconceptions about the concept. Therefore, the teacher will also ask these students why rate of reaction will increase. Students may say that “as the concentration increases, the activation energy decreases; thus, the number of particles exceeding activation energy increases and as a result, reaction rate increases” or “when the concentration of a substance increases, because of the increase in kinetic energy, the rate of reaction increases”.

Later, in order to enhance students' awareness of their misconceptions and dissatisfaction with their own conceptions, the teacher will ask more questions addressing some points such as the relationship between the increase in concentration and the number of effectively colliding particles.

Teacher: How will the number of effectively colliding particles in a reaction change if the concentration of a reactant will be increased?

When students think about this question, they may realize their answers are not correct. Thus, in discussion environment, the students will be dissatisfied with their conceptions. If students have difficulties in replying questions, the teacher will encourage them providing some prompts to reply the questions. After this discussion session, teacher will continue the instruction by explaining the relationship between the concentration and the rate of reaction.

Intelligibility

Teacher: As you remember from collision theory, atoms and molecules must collide with sufficient energy to produce an activated complex that produces new molecules. That is, a reaction between two substances can only occur when they undergo effective collisions. The number of such collisions in unit time depends on how often the molecules get into contact; that is on their concentration. The possibility of collisions among these reactants increases as the concentration of reactants increases. Increased collisions provide an opportunity for a greater number of effective collisions to occur, thereby increasing the rate of reaction. Let's see the effect of concentration on rate of reaction through a demonstration.

Teacher will present the demonstration related to the effect of concentration on reaction rate. In this demonstration, the reaction between baking soda ($NaHCO_3$, sodium hydrogen carbonate) and vinegar (CH_3COOH, acetic acid), will be carried out (See Appendix I).

Teacher: When baking soda ($NaHCO_3$, sodium hydrogen carbonate) is added to a acidic batter containing foods such as lemon juice or vinegar, a neutralization reaction occurs that produces carbon dioxide gas. This gas gets trapped in the batter and causes it to rise during baking. The acetic acid found in vinegar is one of the natural acids in cooking.

The teacher will write the reaction between sodium hydrogen carbonate and acetic acid on board. This reaction as follows:

$NaHCO_{3(s)} + HC_2H_3O_{2(aq)} \rightarrow NaC_2H_3O_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

Teacher: How is the rate of carbon dioxide production related to the concentration of acid?

The teacher will make the students think and say that the rate of this reaction will be observed by checking the amount of carbon dioxide gas produced in a determined time interval.

After these explanations, the teacher will perform this demonstration with the vinegar in three different concentrations: %100, %50, and %25 (See Figure I.2, I.3, and I.4). Through this demonstration, these students will be shown that rate of a reaction will increase when the concentration of a reactant increases and vice versa.

After the demonstration, a discussion session will be carried out with the students. Teacher will ask questions with respect to this demonstration.

Teacher: What did you observe in this demonstration? What do you think about the reason for this event?

Through the discussion environment, teacher will encourage students to establish a link between the effect of concentration on the rate of reaction and their observations during the demonstration. Thus, the students will understand that the increase in the concentration of a reactant will increase the rate of reaction. In consequence, the concept will be more intelligible for the students.

Plausibility

After that, the teacher will present new examples, especially examples from daily life, related to this topic in order to enhance students' understanding of the effect of concentration on rate of reaction.

Teacher: Which lime remover causes a higher rate of reaction with lime in a teapot: %5 lime remover or % 25 lime removers?

The teacher also will ask the rationale of students' answers. This question will be discussed by all students. Consequently, the new concept will be more plausible for the students.

Fruitfulness

Finally, the teacher will assign homework to the students on the application of the new concept to a different situation. Since the new concept will help students to explain unfamiliar phenomena and leads to new insights, this concept will be more fruitful to them.

Teacher: I expect you to find some daily life examples related to the effect of change in concentration of reactant on the rate of reaction. You will discuss these examples with your classmates in the following lesson.

APPENDIX I

THE EFFECT OF CONCENTRATION ON RATE OF REACTION

Materials: Vinegar, baking soda ($NaHCO_3$), beakers, side arm flasks or flasks fitted with stoppers and tubing.

Principles and Procedures: When baking soda ($NaHCO_3$, sodium hydrogen carbonate) is added to a acidic batter containing foods such as lemon juice or vinegar, a neutralization reaction occurs that produces carbon dioxide gas. This gas gets trapped in the batter and causes it to rise during baking. The acetic acid found in vinegar is one of the natural acids in cooking. The reaction between sodium hydrogen carbonate and acetic acid as follows:

$$NaHCO_{3(s)} + HC_2H_3O_{2(aq)} \rightarrow NaC_2H_3O_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

The rate of this neutralization reaction can be estimated by measuring the the rate of carbon dioxide production. Construct a gas collection apparatus (See Figure I.1). Place 20 g of baking soda ($NaHCO_3$) in the reaction flask. Fill the graduated cylinder with water and invert in a beaker of water with the top of the cylinder covered with a note card so no water escapes. Remove the stopper from the reaction flask, add 100 mL of fresh vinegar and immediately replace the stopper. Swirl the flask contents to mix thoroughly. Carbon dioxide production begins instantly. Record the time at which a measurable quantity (e.g. 50 mL or 100 mL) of water has been displaced by the time required to replace it. It will be assumed that the rate of water displacement is proportional to the rate of carbon dioxide production. Record the rate of carbon dioxide production for 100% vinegar.

Place 20 g of baking soda in a clean, dry flask and determine the approximate rate of carbon dioxide production (in mL of carbon dioxide gas produced per unit time) using 50% and 25% vinegar.

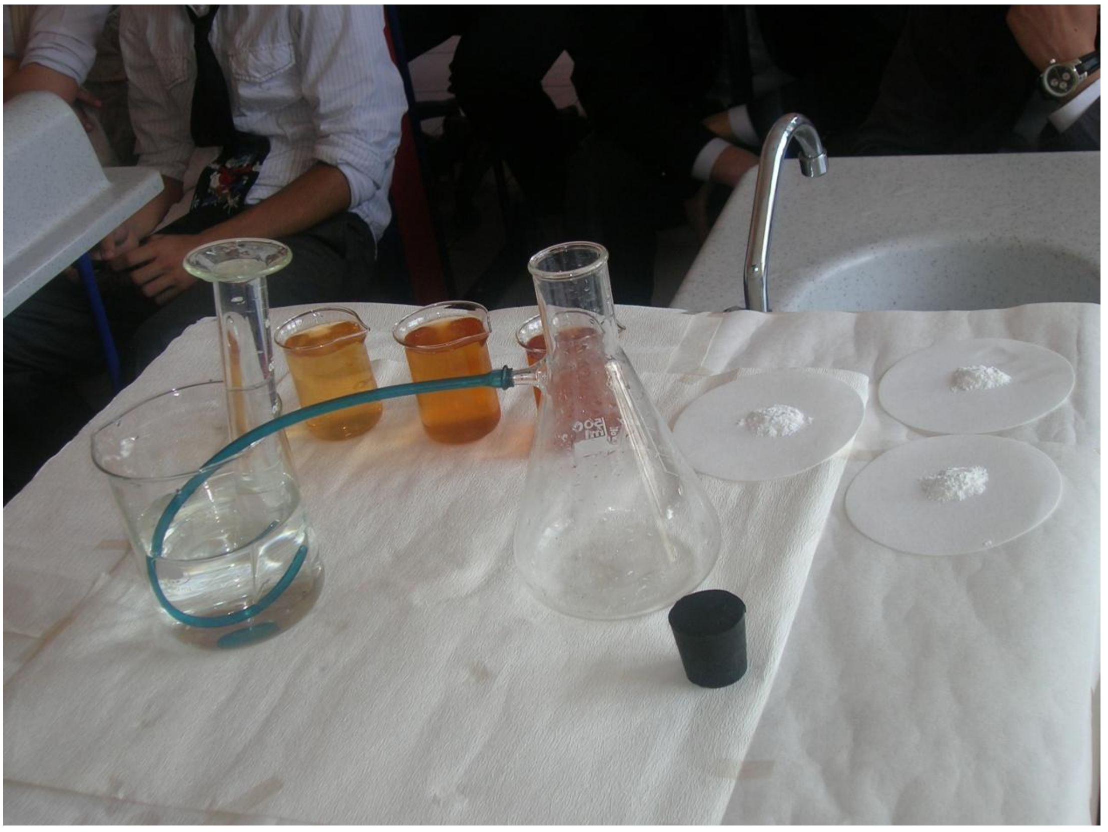


Figure I.1 Reactions between baking powder and vinegar in different concentrations

Figure I.2 Reaction between Baking Powder and 100% Vinegar

Figure I.3 Reaction between Baking Powder and 50% Vinegar

Figure I.4 Reaction between Baking Powder and 25% Vinegar

APPENDIX J

THE EFFECT OF TEMPERATURE ON RATE OF REACTION

Materials: Vinegar, baking soda ($NaHCO_3$), beakers, side arm flasks or flasks fitted with stoppers and tubing.

Principles and Procedures: Determine the approximate rate of carbon dioxide production (in mL of carbon dioxide per unit time) as a function of temperature using the apparatus described in Appendix I. Repeat the investigation using undiluted vinegar at temperatures of approximately 0^0C, 25^0C, and 75^0C. use an ice bath or hot plate to achieve the required temperatures.

APPENDIX K

IODINE CLOCK REACTION

Materials: Beakers, potassium iodate (0.01 M KIO_3), soluble starch, sulfuric acid (1 M H_2SO_4), sodium metabisulfite ($Na_2S_2O_5$), timer, cylinders, distilled water, thermometer.

Principles and Procedures: Make a starch solution by mixing approximately 7 grams of soluble starch in a small amount of warm water. Dissolve this starch paste in a liter of boiling water and then allow it to cool to room temperature. Make a 0.01 M solution of potassium iodate by dissolving 2.1 grams of potassium iodate in a liter of warm water.

Place 5 mL of starch solution in a 250 mL or 500 mL beaker. Add 95 mL of distilled water and 0.02 grams of sodium metabisulfite ($Na_2S_2O_5$) and stir until dissolved. Acidify the solution by adding approximately 5 mL of 1 M sulfuric acid. Measure out 100 mL of 0.01 M potassium iodate solution and start a stopwatch the moment the solutions are mixed. Record the time when the solution turns black. Repeat this procedure at temperatures of approximately 0^0C, 25^0C, and 50^0C. You may cool the solutions in an ice water bath to 0^0C, and you may warm them on a hot plate to approximately 50^0C.

The probable, simplified mechanism for the simple iodine clock reaction as follows:

$IO_3^- + 3HSO_3^- \rightarrow I^- + 3H^+ + 3SO_4^{-2}$ (slow)

$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3\,H_2O$ (slow)

$I_2 + HSO_3^- + H_2O \rightarrow 2I^- + SO_4^- + 3H^+$ (fast)

I_2 + starch $\rightarrow$ starch/iodine complex (blue-black)

IO_3^- reacts with HSO_3^- to form I^-. I^- reacts with IO_3^- to form I_2. I_2 immediately reacts with HSO_3^-. After all the HSO_3^- is consumed, I_2 reacts with starch to form the blue-black colored complex.

Figure K.1 Reaction between Potassium Iodate (KIO_3) and Sodium Metabisulfite ($Na_2 S_2O_5$) at the Temperature of 25^0C

Figure K.2 Reaction between Potassium Iodate (KIO_3) and Sodium Metabisulfite ($Na_2S_2O_5$) at the Temperature of 0^0C

APPENDIX L

CATALYSTS, REACTION RATES, AND ACTIVATION ENERGY

Materials: Hydrogen peroxide (H_2O_2), manganese dioxide (MnO_2)

Principles and Procedures: Hydrogen peroxide is a colorless liquid used as a rocket propellant, disinfectant and bleaching agent. You may have used a dilute hydrogen peroxide solution to sterilize a wound. Hydrogen peroxide slowly decomposes into water and oxygen:

$$2\ H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

This process can be accelerated by the addition of numerous substances, particularly salts of such metals as iron, copper, manganese, nickel or chromium. It should be noted that these substances accelerate the decomposition of hydrogen peroxide, but are not consumed in the process. Such substances are known as catalysts.

Place 3 grams of manganese dioxide in a large test tube. Add 5 mL of 3% hydrogen peroxide into this tube (See Figure L.1). Observe the reaction. Now add more hydrogen peroxide and continue to observe the reaction. Note that the manganese dioxide is not used up in the reaction. It remains visible in the tube, and promotes the decomposition of hydrogen peroxide repeatedly. Manganese dioxide is therefore considered to be a catalyst, and the reaction can be written:

$$2\ H_2O_{2(aq)} \xrightarrow{MnO_2} 2H_2O_{(l)} + O_{2(g)}$$

Figure L.1 Reaction between Hydrogen Peroxide (H_2O_2) and Manganese Dioxide (MnO_2)

APPENDIX M

THE EFFECT OF SURFACE AREA ON RATE OF REACTION

Materials: Solis zinc pieces (Zn), dust zinc (Zn), 20% hydrochloric acid (HCl)

Principles and Procedures: Reactions involving solids take place at the surface of the solid. The particles of the other reactant, gas or liquid, can only collide with the particles of the solid at its surface. Therefore, the larger the contact surface, the greater the chance that the molecules of the reactants may come together. In consequence, the rate of the reaction increases.

Construct a gas collection apparatus (See Figure M.1). Place 10 g of solid zinc pieces in the reaction flask. Add 25 mL 25% hydrochloric acid (HCl). Hydrogen production begins instantly. Record the time at which a measurable quantity (e.g. 25 mL) of water has been displaced by the time required to replace it. It will be assumed that the rate of water displacement is proportional to the rate of hydrogen production. Record the rate of hydrogen production for solid zinc pieces. The reaction between zinc (Zn) and hydrochloric acid as follows:

$$Zn_{(s)} + 2H^{+}_{(aq)} \rightarrow Zn^{+2}_{(aq)} + H_{2(g)}$$

Then, place 10 g of dust zinc in a clean, dry flask and determine the approximate rate of hydrogen production (in mL of hydrogen gas produced per unit time) using 25 mL 25% hydrochloric acid (HCl).

Figure M.1 Reaction between Solid Zinc Pieces (Zn) and Hydrochloric Acid (HCl) and Reaction between Dust Zinc (Zn) and Hydrochloric Acid (HCl)

APPENDIX N

THE EFFECT OF REACTANT TYPE ON RATE OF REACTION

Materials: Aluminum (Al), magnesium (Mg), 20% hydrochloric acid (HCl)

Principles and Procedures: the rate of a reaction depends on the number of effective collisions that occur in a given amount of time. If a favorable geometry is assumed, then each collision with energy equal to or greater than activation energy is effective. Activation energy depends on the nature (type) of the reactant molecules and is different for different reactions.

Construct a gas collection apparatus (See Figure N.1). Place 10 g of aluminum (Al) in the reaction flask. Add 25 mL 25% hydrochloric acid (HCl). Hydrogen production begins instantly. Record the time at which a measurable quantity (e.g. 25 mL) of water has been displaced by the time required to replace it. It will be assumed that the rate of water displacement is proportional to the rate of hydrogen production. Record the rate of hydrogen production for aluminum. The reaction between aluminum (Zn) and hydrochloric acid (HCl) as follows:

$$Al_{(s)} + 2H^{+}_{(aq)} \rightarrow Al^{+3}_{(aq)} + H_{2(g)}$$

Then, place 10 g of magnesium (Mg) in a clean, dry flask and determine the approximate rate of hydrogen production (in mL of hydrogen gas produced per unit time) using 25 mL 25% hydrochloric acid (HCl). The reaction between aluminum (Mg) and hydrochloric acid (HCl) as follows:

$$Mg_{(s)} + 2H^{+}_{(aq)} \rightarrow Mg^{+2}_{(aq)} + H_{2(g)}$$

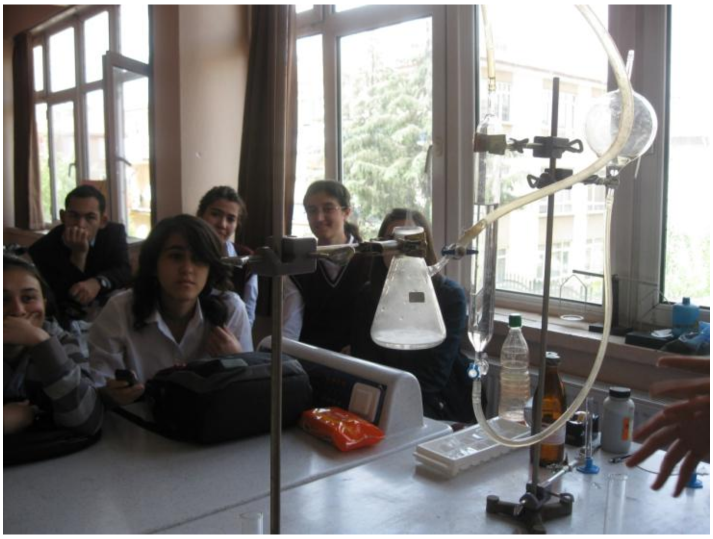


Figure N.1 Reaction between Hydrochloric Acid (HCl) and Aluminum (Al) and the Reaction between Hydrochloric Acid (HCl) and Magnesium (Mg)

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Kaya, Ebru
Nationality: Turkish
Date and Place of Birth: 03 November 1980, İzmir (Turkey)
Marital Status: Single
Phone: +90 312 210 3659
E-mail: ekaya@metu.edu.tr

EDUCATION

Degree	**Institution**	**Year of Graduation**
Integrated BS and MS	Dokuz Eylül University, Secondary Science and Mathematics Education	2003
High School	Ortaklar Anatolian Teacher Training High School	1998

RESEARCH INTEREST

Conceptual Change Approach, Argumentation in Science, Philosophy of Chemistry

FOREIGN LANGUAGES

Advanced English

HOBBIES

Swimming, Scuba-Diving, Tennis, Salsa, Tango.