# EFFECT OF CONCEPTUAL CHANGE TEXTS ACCOMPANIED WITH ANALOGIES ON UNDERSTANDING OF CHEMICAL BONDING CONCEPTS

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## ABSTRACT

**EFFECT OF CONCEPTUAL CHANGE TEXTS ACCOMPANIED WITH ANALOGIES ON UNDERSTANDING OF CHEMICAL BONDING CONCEPTS**

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The major purpose of this study was to explore the effects of conceptual change texts oriented instruction accompanied with analogies over traditionally designed chemistry instruction for $9^{th}$ grade students' understanding of chemical bonding concepts. Also, the effect of instruction on students' attitude toward chemistry as a school subject and the effect of gender difference on understanding of chemical bonding concepts and attitudes toward chemistry were investigated.

The subjects of this study consisted of 41 ninth grade students from two classes of a chemistry course in TED Ankara High School. This study was conducted during the 2003-2004-spring semester. The classes were randomly assigned as control and experimental groups. Students in the control group were instructed by traditionally designed chemistry instruction whereas students in the experimental group were instructed by the conceptual change texts oriented instruction accompanied with analogies. Chemical Bonding Concepts Test was administered to

both groups as a pre-test and post-test in order to assess their understanding of concepts related to chemical bonding. Students were also given Attitude Scale toward chemistry as a school subject at the beginning and end of the study to determine their attitudes and Science Process Skill Test at the beginning of the study to measure their science process skills. At the end of the study, we administered interviews to the students.

The hypotheses were tested by using analysis of covariance (ANCOVA) and two-way analysis of variance (ANOVA). The results revealed that conceptual change texts oriented instruction accompanied with analogies caused a significantly better understanding of scientific conceptions related to chemical bonding concepts than the traditionally designed chemistry instruction. In addition, these two modes of instruction developed the similar attitude toward science as a school subject. Also, science process skill was a strong predictor in understanding the concepts related to chemical bonding. On the other hand, no significant effect of gender difference on understanding the concepts about chemical bonding and on students' attitudes toward chemistry as a school subject was found.

KEYWORDS: Misconception, Traditional Instructional Method, Conceptual Change Text, Analogy, Chemical Bonding, Attitude Towards Chemistry as a School Subject, Science Process Skill.

# ÖZ

## BENZEŞTİRMELERLE VERİLEN KAVRAMSAL DEĞİŞİM METİNLERİNE DAYALI ÖĞRETİMİN KİMYASAL BAĞLARLA İLGİLİ KAVRAMLARI ANLAMAYA ETKİSİ

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Bu çalışmanın amacı kavramsal değişim metinleri ve analojilerin 9. sınıf öğrencilerinin kimyasal bağlarla ilgili kavramları anlamalarına etkisini geleneksel yöntem ile karşılaştırarak incelemektir. Ayrıca, öğretim yönteminin ve cinsiyet farkının öğrencilerin kimya dersine yönelik tutumlarına etkisi ile cinsiyet farkının başarıya etkisi de araştırılmıştır.

Çalışmanın örneklemini TED Ankara Lisesinin iki ayrı sınıfındaki 41 lise birinci sınıf öğrencisi oluşturmuştur ve çalışma 2003-2004 bahar döneminde gerçekleştirilmiştir. Sınıflar kontrol grubu ve deney grubu olarak rasgele seçilmiştir. Kontrol grubunda geleneksel yöntem kullanılırken deney grubunda kavramsal değişim metinleri ve analojiler kullanılmıştır. Öğrencilerin kimyasal bağlarla ilgili kavramları anlama seviyelerini ölçmek için Kimyasal Bağlar Kavram Testi her iki

ruba ön-test ve son-test olarak uygulanmıştır. Ayrıca, öğrencilerin kimya dersine yönelik tutumlarını belirlemek için Kimya Dersi Tutum Ölçeği ve bilimsel işlem becerilerini belirlemek için Bilimsel İşlem Beceri Testi her iki gruba da uygulanmıştır. Çalışma sonucunda, öğrencilerle mülakat yapılmıştır.

Araştırmanın hipotezleri ortak değişkenli varyans analizi (ANCOVA) ve iki yönlü varyans analizi (ANOVA) kullanılarak test edilmiştir. Sonuçlar kavramsal değişim metinleri ve analojiler kullanılarak uygulanan öğretim yönteminin kimyasal bağlarla ilgili kavramların anlaşılmasında geleneksel kimya öğretim yöntemine göre daha etkili olduğunu göstermiştir. Her iki öğretim yönteminin öğrencilerin kimya dersine yönelik tutumlarını istatistiksel açıdan benzer derecede geliştirdiği gözlenmiştir. Bilimsel işlem becerisinin de öğrencilerin kimyasal bağlarla ilgili kavramları anlamalarına istatistiksel olarak anlamlı katkısı olduğu saptanmıştır. Cinsiyet farkının kimyasal bağlar konusunu anlama ve kimya dersine yönelik tutuma bir etkisinin olmadığı ortaya çıkmıştır.

ANAHTAR SÖZCÜKLER: Kavram Yanılgısı, Kavramsal Değişim Metni, Analoji, Geleneksel Yöntem, Kimyasal Bağlar, Kimya Dersi Tutum Ölçeği, Bilimsel İşlem Becerisi

To my family

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## TABLE OF CONTENTS

# LIST OF TABLES

TABLE

## LIST OF FIGURES

# LIST OF SYMBOLS

CCTIA : Conceptual Change Text Oriented Instruction Accompanied With Analogies

TDCI : Traditionally Designed Chemistry Instruction

CBCT : Chemical Bonding Concepts Test

ASTC : Attitude Scale Towards Chemistry as a School Subject

SPST : Science Process Skill Test

df : Degrees of freedom

SS : Sum of squares

MS : Mean square

$\overline{X}$ : Mean of the sample

P : Significance level

F : F statistic

# CHAPTER I

# INTRODUCTION

During the last century we have moved from the Industrial Age through the Information Age to the Knowledge Age. The ability to obtain, assimilate and apply knowledge effectively will become a key skill in the next century. In this sense, student understanding of scientific knowledge became the most important subject of the science education researchers (Fisher, 1985; Chambers and Andre, 1997). Unfortunately, research studies have found that many students pass their science courses without acquiring a proper understanding of some of the concepts. Students have problems in using scientific concepts, principles, laws and formulas in solving problems or using them for further applications and they often solve questions using memorized facts and algorithms. In other worlds, many students tend not to learn meaningfully and thus may have difficulty relating what is taught to them in science with other science ideas, and with real world experiences (Novak, 1988). Instead, much of their learning tends to involve memorization of facts in which newly learned materials is not related in ways that make sense to the learner (Novak, 1988).

David Ausubel was one of the first researchers to study the connection between meaning and learning (Novak, 1993). He stated that for meaningful learning to occur, new knowledge must be related by the learner to relevant existing concepts in that learner's cognitive structure. For this reason, Ausubel (1968) said that, "The most important single factor influencing learning is what the learner already knows". This idea of Ausubel has been the guide to many science education researchers and their studies (i.e., Novak, 1993). These studies have consistently shown that students do not come to classroom with blank slates (Posner, Strike, Hewson and Gertzag, 1982). In fact, students from the moment of birth infants need to make sense of their world. They construct their own explanations for how and why things behave as they do. So, long before they begin formal schooling, children have made meaning of their everyday experiences. And, they will construct new knowledge on their previous conceptions. Ausubel (1968) has labeled these conceptions as “preconceptions”. As accepted by many scientists, this prior knowledge can be a bridge to new learning or a barrier (Pines, 1978; Pines and Novak, 1985, Ausubel, 1968; Novak, 1977).

When students’ preconceptions are different from the views of scientists, these differing frameworks are referred to in the literature as “misconceptions” (Helm, 1980; Fisher, 1985; Cho, Kahle, and Nordland, 1985; Griffiths and Grant, 1985); “preconceptions” (Novak 1977); “alternative conceptions” (Driver and Easley 1978; Driver and Erickson, 1983; Nakhleh, 1992; Palmer, 2001); or “children’ science” (Gilbert, Osborne, and Fensham, 1982). In this study, the term “misconception” will be used to refer to the students’ conception that is inconsistent with scientific conception.

Since new knowledge is linked to the existing conceptions, misconceptions affect further learning negatively. So, misconceptions are really big obstacles to promote meaningful learning. Teacher must identify students’ misconceptions and find out to prevent them from occurring. Many studies have shown that students’ misconceptions may arise prior to formal instruction as a result of variety of contacts students make with the physical and social world (Strauss, 1981) or as a result of interactions with teachers (Gilbert and Zylberstajn, 1985) or from textbooks (Cho et al., 1985). These findings are crucial because by taking the sources of misconceptions into account, removing of misconceptions could be achieved.

Since misconceptions cover a large range of science concepts, science educators in many countries have focused their attention upon students’ misconceptions at science concepts (Osborne and Wittrock, 1983). Studies in science education aimed to determine the students' understandings of chemistry concepts indicated that students have considerable degree of misconceptions about many chemistry concepts: the mole (Staver and Lumpe, 1995); chemical equilibrium (Gussarsky and Gorodetsky, 1988; Camacho and Good, 1989; Pardo and Solaz-Patolez, 1995); electrochemistry (Garnett, 1992); solutions (Ebenezer and Ericson, 1996; Abraham et al., 1994) and the particulate nature of matter (Gabel et.al., 1987).

Chemical bonding concept is one of the chemistry topics where students have great difficulty and promoting meaningful learning is too difficult for this topic. Because it includes abstract concepts, and some words from everyday language are used with different meanings. Also, understanding chemical bonding requires some chemistry topics (i.e., concepts of atom and molecule, electronegativity) and physics topics (i.e., energy and force) in which students hold wrong conceptions. Thus, researchers have identified a lot of misconceptions in the area of chemical bonding. These studies provide us with a rich knowledge base of students' misconceptions in chemical bonding.

Many of the misconceptions are pervasive, stable, and resistant to change and some students persist in giving answers consistent with their misconceptions despite years of formal schooling in science (Driver and Easley, 1978; Fredette and Lockhead, 1980; Osborne, 1983). Traditional approach to science instruction has been consistently shown to be ineffective in engaging student interest or developing conceptual understanding of the subject matter (Driver, 1983; Anderson and Smith, 1987; Bishop and Anderson, 1990; Tobias, 1990; Haider and Abraham, 1991). Most of current traditional teaching is focused on the content of the curriculum and on knowledge and information transmission. Although this will remain an essential aspect of teaching, it is no longer enough for an effective and stimulating learning process because knowledge cannot be transmitted to the learner's mind by the teacher. Instead, students construct their knowledge by making links between their ideas and new concepts through experience they acquire in school or daily life. These observations lead to a new approach to education called "constructivist approach". A constructivist approach sees learners as mentally active agents struggling to make sense of their world (Pines and West, 1986). Also, it allows students to construct knowledge, to think and to learn.

Constructivist ideas have had a major influence on science educators over the last decade (Appleton, 1997). Several models of learning in science based on constructivist approach such as learning cycle approach (Stepans, Dyvhe and Beiswenger, 1988), inquiry approach (Marten-Hansen, 2002), conceptual change model (Posner et al., 1982) and bridging analogies approach (Brown and Clement, 1989).

Some constructivist science educators have chosen the use of conceptual change approaches in science education (Gunstone and Northfield, 1992; Hewson and Hewson, 1988; Neale and Smith, 1989; Roth and Rosaen, 1991). Pines and West (1986) also gave the big importance to conceptual change to deal with the students' misconceptions. They suggested that conceptual learning occurs when learners make their own sense about knowledge. One of the conceptual change strategies to dispel students' misconceptions is the use of refutational or conceptual change texts (Guzzetti et.al., 1993; Dole and Niderhauser, 1990; Maria and MacGinite, 1987; Chambers and Andre, 1997; Markow and Lonnning, 1998; Hynd, McWhorter, Phares and Suttles, 1994). The meaning of the textual information is not derived wholly from the reading of the text, but from the interaction of the reader with textual information. They are designed to make readers aware of the inadequacy of their intuitive ideas and help students understand and apply the target scientific concept through the use of explanations and examples Hynd et.al. (1994).

Besides this, analogy can also be an instructional and knowledge creating strategy that provides the students opportunities to work with their existing concepts and construct their knowledge. It has frequently argued that analogies are the valuable tools in teaching and learning difficult scientific concepts (Webb, 1985; Brown, 1992).

This study was concerned primarily with students' misconceptions and instructional strategies to affect the learning of scientific concept, and to elicit conceptual change from naïve to scientific conceptions. In this respect, we aimed to improve ninth grade students' conceptual change concerning chemical bonding concept by combining analogy and conceptual change text.

Many science education research studies has focused on identifying cognitive variables that affect students' achievement and their understanding of science concepts (for example, BouJaodue, 1992; Cavallo, 1996; Cavallo and Schafer, 1994; Lawson, 1983; Niaz and Lawson, 1985; Noh and Scharman, 1997) such as science process skills. Science process skills involve identifying variables and hypotheses, designing investigations, graphing and exploring data, explaining results and drawing conclusions. Lazarowitz (2002) indicated that learning science requires high cognitive skills. In this study, the contribution of students' science process skills to their understanding of chemical bonding concepts was examined.

In present study, we also dealt with the effect of treatment on students' attitudes toward science as a school subject. Much research in science education indicated that the type of instruction affected students' attitudes toward science as a school subject (Chang, 2002; Parker, 2000). Students' attitudes, feelings and perceptions of science are important for science achievement.

# CHAPTER II

# REVIEW OF LITERATURE

In recent years, student understanding of scientific knowledge became the most important subject of the science education researchers (Fisher, 1985; Chambers and Andre, 1997). The aim of these studies is to improve students' understanding of science concepts and use them for intended purposes. In 1988, Goodman and Elgin defined knowledge as an effort starting from certain truths and searching to discover other truths through observation and experiment and so arriving at accurate and comprehensive description of the real world. Moreover, Pines and West (1986) discriminated, following Vygotsky, two sources of individual knowledge as spontaneous and formal knowledge. The spontaneous knowledge comes from children interactions with their environment and previous conceptions. The primary characteristic of this knowledge is that it constitutes children' reality. Also, the learner freely without the time restriction and any predetermined direction can learn it. This spontaneous knowledge is of great influence on what the can and will learn. Formal knowledge is another type of knowledge, which was acquired from the planned instruction, usually school setting. The source of this knowledge is the authority and it is scientifically accepted one. Students set out to learn a particular body of knowledge and are expected to master it after a period of time. However, students' mastering the knowledge is not an easy task because the acquisition of formal knowledge is profoundly influenced by spontaneous knowledge and sometimes students' existing knowledge might be a problem to learn new ones. This problem will arise when spontaneous knowledge does inconsistent with scientific knowledge and these different spontaneous knowledge have been described as misconceptions (Fisher, 1985); preconceptions (Novak 1977); or children' science (Gilbert, Osborne, and Fensham, 1982).

## 2.1 Misconceptions

Misconceptions, defined as the ideas that students have about natural phenomena that are inconsistent with scientific conceptions, are pervasive, stable, and often resistant to change at least through traditional instruction (Fisher, 1985). In order to dispel students' misconceptions, it is necessary to identify the sources of these misconceptions.

According to Yip (1998) misconceptions mainly arise from three sources as:

1- naïve ideas arising from everyday experiences and language usage of learners;

2- erroneous concepts formed by the learners during the lessons due to misunderstanding or lack of understanding; and

3- misconceptions passed from teachers through wrong or inaccurate teaching.

Students' misconceptions on chemical bonding can be an example of misconceptions arising from everyday experiences and language usage. Boo (1998) reported that meaning of the term "bond" varied in daily life, and in school. For example, in daily life, the term "bond" is often used in the sense of a physical link (i.e., a glue which holds two pieces of materials together), which entails the idea that energy is needed to make a link.

Another possible source of students' misconceptions is macroscopic reasoning. Haidar and Abraham (1991) suggested that chemistry curriculum needed to be revised in a way that promotes connections between students' macroscopic experiences and their scientific microscopic explanations. Students need instruction that will help them develop the link between the macroscopic observations in the laboratory and the microscopic models that chemists use to explain them.

Boo (1998) also reported the same arguments about microscopic representations. He found that the students have difficulty in atoms and molecules related to attribution of macroscopic properties to microscopic particles. Therefore, chemistry teachers should try to facilitate learner's conceptualization from the macroscopic world to the microscopic world.

According to Taber (1995), teacher themselves also may cause misconceptions. They may misunderstand the context. Also, although instruction is accurate, students may misunderstand some concepts due to inadequate prerequisite knowledge.

Another source of misconceptions might be textbooks (De Posada, 1999; Hurst, 2002) because they are used far more than any other educational material (i.e., slides, videotapes) in science education. So, they influence what and how students learn. Also, many researchers have suggested that a major source of students' misconceptions comes from imprecise and inappropriate language used by textbooks in explaining chemical bonding concepts (Boo, 1998; Garnett and Treagust, 1990; Ogue and Bradley, 1994; Sanger and Greenbowe, 1997).

The most common approaches for obtaining information in misconceptions research are through interviews with students and/or open-ended responses to questions on specific science topics. Interview methodologies have acquired strong support as a viable approach (Osborne, and Gilbert, 1980) and they have been used by many researchers to diagnose students' misconceptions: covalent bonding and structure (Peterson, Treagust, and Garnett, 1989), chemical bonding (Coll and Treagust, 2003; Boo, 1998), hydrogen bonding (Henderleiter et.al., 2001). Also, it has possible limitations for use by classroom teachers. For example, teachers require time to administer individual interviews, and the fact that many science teachers are not trained to conduct interviews, to record and transcribe data, or to interpret findings (Peterson and Treagust, 1989).

An alternative approach for identifying misconceptions is to use multiple-choice pencil-and-paper instrument, which are easily administered and scored. Typical multiple-choice instrument only tested content, whereas the diagnostic test, a version of multiple-choice instruments, recommended the use of student reasoning including known misconceptions to formulate test items (Treagust, 1988, 1995)

These findings are crucial because by taking the sources of misconceptions into account, remediation of misconceptions could be achieved. However, teachers, generally, are not aware of students' alternative conceptions and therefore there may occur problems in teaching and learning. Investigating students' conceptions not only reveals important insights about students' way of thinking and understanding in science but also can help researchers and teachers revise and develop their own science knowledge (Treagust, Duit, and Fraser, 1996).

If students' misconceptions could not be eliminated, they affect their further learning negatively. Therefore, it is necessary to overcome these misconceptions with the help of different instructional methods. However, it is not an easy task. Because some student misconceptions are very resistant to instructional change, and some students persist in giving answers consistent with their misconceptions even after large amount of instruction (Anderson and Smith, 1987; Driver and Easley, 1978; Fredette and Lockhead, 1980; Osborne, 1983)

### 2.2. Misconceptions related to Chemical Bonding

Chemical bonding is a basic chemical principle that has applications in all areas of chemistry. Indeed, these concepts are often revisited in each successive chemistry course that students take. Further, bonding is the cognitive key that students need to be able to unlock the door to understanding the microscopic world of chemistry. However, most of the students have difficulty in understanding the concepts in chemical bonding (Tan, and Treagust, (1999). One possible reason of that chemical bonding is an abstract and theoretical topic. In addition, understanding chemical bonding requires prerequisite knowledge such as the particulate nature of matter, electronegativity, energy and force in which students have difficulty in understanding. As a result, students hold many misconceptions related to chemical bonding concepts. Therefore, students' misunderstanding in chemical bonding constitutes a major problem of concern to science education researchers, teachers and students. Many researchers identified the misconceptions about chemical bonding and its related topics.

Nicoll (2001) examined that how undergraduate chemistry students think about bonding concepts. In his study, he investigated the students' misconceptions related to electronegativity, bonding geometry, and microscopic representations that undergraduate chemistry students hold. This work is also established that some students' misconceptions relating to bonding are resistant to change despite increased chemistry education. Students' difficulties related to bonding can be summarized as follows:

- Confuse the definition of ionic and covalent bonding
- Failing to define polarity in term of electronegativity.
- Not distinguishing between atoms and molecules.
- Failing to explain why bonding occurs.
- Failing to explain why molecules adopted the geometries that they did.
- Failing to define octet rule.

The most common misconception among students was about the ionic bonding, especially ionic bond within NaCl. Taber (1997) investigated students' misconceptions dealing specifically with ionic bonding. In his work, he established that students do have difficulty understanding ionic bonding and as a solution he proposed presenting ionic bonding in terms of a molecular framework. He described the common aspects of the alternative conceptions as a "molecular framework" and it is contrasted with the curricular science version, referred to as the "electrostatic framework". There are three related ideas in molecular framework (Taber, 1994), which are the valency conjecture, the just force conjecture, and the history conjecture. The valency conjecture implies that the atomic electronic configuration determines the number of ionic bonds formed. The just force conjecture explains the attraction between ions that have not been involved in electron transfer as just due to forces, rather than ionic bonding. And, the history conjecture implies that bond are only formed between atoms that donate/accept electrons.

Butts and Smith (1987) also reported similar findings. They analyzed grade 12 students' understanding of structure and properties of molecular and ionic compounds. They found that most students cannot understand the three dimensional nature of ionic bonding in NaCl. Some students think that the nature of the electron transfer process from sodium atom to chlorine atom which results in the formation of the bond. Also, others believe that NaCl exist as molecules and these molecules were held together by covalent bonds.

The one of the most common approaches for obtaining information in misconceptions research is using multiple-choice pencil-and-paper diagnostic instrument. Peterson, Treagust and Garnett (1989) developed a multiple-choice diagnostic instrument to measure grade 11 and 12 students understanding of covalent bonding and structure and described the misconceptions by using this instrument. This diagnostic instrument was composed of 15 two-tier multiple-choice items. The first tier of each item consists of a content question having two, three, or four possible reasons for the answer given in the first tier, which included the correct answer and three alternatives reasons involving misconceptions. The alternative reasons and misconceptions were identified from unstructured interviews, students' concept maps and open-ended pencil-and-paper test items. This test was administered to 159 11$^{th}$ grade and 84 12$^{th}$ grade high school students. The following misconceptions that students hold were stated as follows:

- Equal sharing of electron pairs occurred in all covalent bonds.
- The polarity of a bond is dependent on the number of valance electrons in each atom involved in the bond.
- Ionic charge determines the polarity of the bond.
- Bond polarity determines the shape of a molecule.
- The shape of a molecule is due to equal repulsion between the bonds only.
- The shape of a molecule only influenced by nonbonding electron pairs in a molecule.
- Intermolecular forces are molecules within a molecule.
- Covalent bonds are broken when a substance changes state.

- Nonpolar molecules formed when the atoms in the molecule have similar electronegativies.
- Nitrogen atoms can share five electron pairs in bonding.
- High viscosity of molecular solid is due to strong bonds in the covalent lattice.

Birk and Kurtz (1999) used this diagnostic test developed by Peterson, Treagust and Garnett (1989) to determine the retention of specific misconceptions about molecular structure and chemical bonding over a time. They administered this test to chemistry students ranging from high school to graduate school and to chemistry faculty. The researchers perceived the teachers' experience as directly related with the years of study at they spend in their field. The results of this study indicated that experience in chemistry helps in gaining both recall and conceptual knowledge. However, even in the faculty level, there was a gap between conceptual understanding and recall knowledge.

Tan and Treagust (1999) also developed a two-tier multiple-choice diagnostic instrument to determine 14-16 year-old students' alternative conceptions related to chemical bonding. Items were developed through interviews with students, students' concept maps, questions of past exams and personal teaching experiences. Then, it was administered to 119 chemistry students in a secondary school. They found that most students have many misconceptions in chemical bonding concept. The common misconceptions can be grouped under the categories of bonding, lattices, intermolecular and intramolecular forces and electrical conductivity of graphite.

The other common approach for obtaining information in misconceptions research is through interviews with students. Henderleiter et.al. (2001) used interview techniques to identify that how students completing a two-semester organic sequence understand and apply hydrogen bonding. They designed 11 interview questions to probe students' understanding of hydrogen bonding. According to their findings, some second year college students still had misconceptions found in less experienced students. For example, students did not recognize the necessity of unpaired electrons and the necessity for hydrogen to be directly bonded to an electronegative atom for hydrogen bonding occurs.

Students have difficulty in understanding of chemical bonding and energetic. In 1998 Boo studied to investigate the grade 12 students' understanding of chemical bonding and energetic through semistructured interviews. He found in his study that:

* Most of the students confused ionic and covalent bonding with each other, and with other kinds of bonds.

* Some students believed that in aqueous sodium chloride there are ionic bonds existing between sodium ions and chloride ions.

* Half of the students confused the concept of element with the concept of compound or of atom with ion.

* Majority of students believed that bond making requires input of energy and bond breaking release energy.

Hapkiewicz (1991) also found similar findings. He revealed that most of the students believe that breaking chemical bond release energy and this misconception were found to be extremely robust to change even after developing the concept of chemical bond formation in terms of thermodynamics. He claims that the reason for this misconception is that use of vague language to chemical bonding in textbooks. Moreover, Gabel et.al (1987) suggested that many students' difficulties with chemical bonds and energetic could be traced to their lack of understanding of the particulate nature of matter. They determined prospective elementary teachers lack conceptual understanding of the particulate nature of matter through interviews.

Coll and Treagust (2003) examined secondary school, undergraduate and graduate level students' mental models for chemical bonding through interview. The results of this study showed that students at all educational levels possess alternative conceptions and prefer to use simple mental models. Also, they fail to relate the theory of the model to practical use. In addition, although students' models might be correct and helpful in some contexts, there are limitations of their model that prevent application and they saw their models as correct. Therefore, the researchers recommended that teachers should inform students about the limitations of their model and emphasize the link between macroscopic and microscopic level since the students couldn't easily shift between them.

Taber (2003) examined college students' mental models for bonding and structure of metals. His study strongly emphasized that students' prior knowledge influence their mental model and learning. He found that students use their knowledge of ionic and covalent bonding in explaining metallic bonding. The instruction may not provide students with appropriate prior learning. Therefore, he suggested that while teaching chemical bonding, first metallic bonding should be introduced and then ionic and covalent bonds should be taught.

Also, textbooks influence what and how students learn. Many researchers have suggested that a major source of students' misconceptions comes from inappropriate language used by textbooks in explaining chemical bonding concepts (De Posada). De Posada (1999) analyzed Spanish high school chemistry textbooks from 1974 to 1998 for grades 9-12 in terms of metallic bonding, how metallic bond is taught and whether textbooks are enough to cause meaningful learning. He designed a questionnaire to analyze textbooks and to find out whether they give opportunity for meaningful learning. Results showed that only a few textbooks' approach is constructivist. Moreover, analogies used in the textbooks present more differences between target and source than similarities, thus these analogies cause misconceptions in students who cannot think in abstract terms and students couldn't understand the relationship between the theoretical model and experimental facts.

Hurst (2002) also analyzed ten chemistry textbooks in terms of how they teach molecular structure. He found that all of these textbooks gave a lot of theories to the students to explain molecular structure and this is the reason why students have such trouble with molecular structure. He thought students who have learned one theory well than students who have been exposed to several theories but know none of them well. So, the number of these theories must be reduced to improve students' understanding.

### 2.3 Conceptual Change Approach

Students show wide range of difficulties to learn the basic concepts of science. Discovering the reason of it has been target of many studies (Fisher, 1985; Chambers and Andre, 1997; Boujaoud, S. 2004; Nakhleh, M. B. 1992). Unfortunately, results of these research studies have shown that students often pass tests by naming facts without change their ideas about how the world works as they do as a consequence science teaching. Also, when they are asked to describe, explain, or make prediction about real-world phenomena, they find their memorized facts and algorithms useless and return to their familiar real-world conceptions. In sum, students have difficulty in learning science because they are not constructing appropriate understandings of fundamental science concepts from the very beginning of their studies. Therefore, they cannot fully understand the more advanced ones.

Actually, learning in science requires more than just adding new concepts to the knowledge. It often requires realignment in thinking and construction of new ideas that may be in conflict with earlier ideas. That is, learning is the result of the interaction between what the student is taught and his current ideas. In 1986, Pines and West used Vygotsky's vine metaphor to describe this interaction of formal and informal knowledge. In their metaphor, the informal knowledge was represented as upward growing vine (to highlight that it is part of the organic growth of the learner) and the formal knowledge is seen as a downward growing vine (suggesting its imposition on the learner from the authorities above). They suggested that meaningful learning occurs when two vines become intertwined with the new formal knowledge serving the purpose of making sense of the world of experiences of child.

The most important proponent of meaningful learning in science teaching was David Ausubel (1968). He explained the critical distinction between "rote learning" and "meaningful learning". In rote learning, new knowledge is not associated with prior concepts, whereas meaningful learning requires students to connect newly introduced concepts to more general prior learned. However, providing a meaningful learning is not an easy task. The problem in meaningful learning is that whether pupils really construct all the knowledge in a scientifically accepted way by themselves. This can be overcome by using instructional strategies other than the traditional methods. Because traditional approach to science instruction has been consistently shown to be ineffective in engaging student interest or developing conceptual understanding of the subject matter (Driver, 1983; Anderson and Smith, 1987; Bishop and Anderson, 1990; Tobias, 1990; Haider and Abraham, 1991).

Different instructional strategies to promote conceptual change have been reported. As mentioned before, one of them is promoting conceptual conflict. Science educators gave the big importance to the conflict situation and they developed teaching strategies to transfer of learners' commitments from one sets of believes to another. Cognitive conflict strategies, derived from a Piagetian constructivist view of learning, are effective tools in teaching for conceptual change (Duit, 1999). These strategies involve creating situations where learners' existing conceptions about particular phenomena or topics are made explicit and then directly challenged in order to create a state of cognitive conflict or disequilibrium. Also, these are aligned with Posner et al.'s theory of conceptual change. He depicted four conditions necessary for this conceptual change to occur: (a) Students must become dissatisfied with their existing conceptions (b) The new conception must be intelligible (c) The new concept must appear plausible (d) The new concept must be fruitful. And, Fellow (1994) suggested that when students accomplish conceptual change they demonstrate thinking that moves them toward accepted scientific understanding and the ability to use those understanding to explain, describe, and predict real-world phenomena. However, promoting conceptual change is a painful process. Because learners have relied on these existing notions to understand and function in their world, they may not easily discard their ideas and adopt a new way of thinking. Thus, simply presenting a new concept or telling the learners that their views are inaccurate will not result in conceptual change as traditional methods did. Teaching for conceptual change requires a constructivist approach in which learners take an active role in reorganizing their knowledge. According to cognitive model, student built understanding of the events and phenomena in their world from their own point of view. The conceptual change model (Posner et al., 1982) is the one of the models of learning in science based on constructivist approach. Conceptual change means the commitment to a new belief about a principle or a phenomenon, and abandoning of an old one. Promoting relatively easy, but it is difficult to get students to abandon their former beliefs (Posner et al., 1982).

### 2.3.1 Conceptual Change Text

In this study, we used conceptual change texts to create cognitive conflict among students, and meaningful learning in students about chemical bonding concepts. Many teachers rely on text-based materials to promote learning (Durkin, 1978-1979). For example, Chambers and Andre (1997) investigated he advantages of using conceptual change text. They stated that most conceptual change approaches are very appropriate for smaller-sized classrooms so the application of them is very difficult in large-scale lectures such as introductory college classes. In this situation, texts can be used to promote conceptual change and text-based conceptual change features may supplement lecturer-presented classroom experiences. They also believed that texts designed to promote conceptual change may reinforce in-class instruction and may help teachers teach in a way that promotes conceptual change even in small-class situations.

Hynd et.al. (1994) analyzed the use of refutational texts. They reported that use of refutational texts was effective in creation of meaningful learning in students about Newton's law of motion. 310 ninth and tenth grade students were randomly assigned within classes to eight groups representing combinations of the three activities (demonstration, student-to-student discussion and a reading a refutational text) and participated in pretest, instruction and posttest. The major differences between the refutational text and the conceptual change text reported by Chambers, and Andre (1997). In the conceptual change text model, students are asked explicitly to predict what would happened in a situation before being presented with information that demonstrates the inconsistency between common misconceptions and the scientific conception. In the refutational text model, common misconceptions are contrasted to scientific conceptions, but the student is not asked first to make a prediction about a common situation before the refutation is given.

However there is a disadvantage that some of the educators think that telling students how the world works in a text can not be as effective having students experience through their directly involvement in scientific notations of the world (Newport, 1990; Osborne, Jones and Stein, 1985).

### 2.3.2. Analogy

Another instructional strategies used to promote conceptual change are the analogical reasoning. Analogy involves an interactive process between what is already known and the new concept presented in instruction. Analogies are believed to promote meaningful learning. Many of the researchers emphasized the power of analogies in connecting information (Harrison, and Treagust, 2000; Brown, 1992; Duit, 1991). For example, Brown and Clement (1989) found that the use of analogies help students to develop their ideas and to serve as a reference point to check on plausibility of their previous explanations. Analogy provides a tool for thinking and explanation and help students to meaningful relations between what they already known and what they are setting out to learn.

Brown (1992) studied the examples and analogies used to remediate misconceptions in physics. The subjects of the study were 21 high school volunteer chemistry students. Each of them was interviewed by the researcher and was presented either text excerpts or bridging explanations that were randomly assigned to different groups. Pre-test and post-test used during the study. Analysis showed significant results in favor of bridging analogies.

In present study, we used analogies to:

1- Make connection between analogies and conceptual change

2- Make concept acquisition

3- Increase students' motivation

4- Increase intelligibility and plausibility of new concepts.

Also, the limitations of analogies were taken into account in this study. Because it has been found that the use of analogies do not always produce the intended results (Webb, 1985). Harrison and Treagust (2000) propose that students understanding breaks down when students mistake analogical models, used by teachers or given in the textbooks, for reality.

As a summary of all these studies, it was found that students have difficulties in understanding chemical bonding concepts, and misconceptions of students about these concepts are resistance to change. Also, if these misconceptions could not be eliminated, they affect further learning negatively. Therefore, teachers, curriculum developers and textbook writers must be aware of students' misconceptions in chemical bonding and try to prevent them from occurring. For this reason, in the present study, we concerned with students' misconceptions and with instructional strategies (analogies and conceptual change texts) to improve the understanding of chemical bonding concept.

# CHAPTER III

# PROBLEMS AND HYPOTHESES

## The Main Problem and Subproblems

### 3.1.1 The Main Problem

The purpose of this study is to compare the effects of conceptual change texts oriented instruction accompanied with analogies and traditionally designed chemistry instruction on 9$^{th}$ grade students' understanding of chemical bonding concepts and attitudes toward chemistry as a school subject.

### 3.1.2 The Subproblems

1. Is there a significant difference between the effects of conceptual change texts oriented instruction accompanied with analogies and traditionally designed chemistry instruction on students' understanding of chemical bonding concepts when their science process skills are controlled as a covariate?
2. Is there a significant difference between males and females in their understanding of chemical bonding concepts, when their science process skills are controlled?
3. Is there a significant effect of interaction between gender difference and treatment with respect to students' understanding of chemical bonding concepts?
4. What is the contribution of students' science process skills to their understanding of chemical bonding concepts?
5. Is there a significant difference between students taught through conceptual change texts oriented instruction accompanied with analogies and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject?

6. Is there a significant difference between males and females with respect to their attitudes toward chemistry as a school subject?

7. Is there a significant effect of interaction between gender difference and treatment with respect to their attitude toward chemistry as a school subject?

### 3.2 Hypotheses

$H_0 1$: There is no significant difference between post-test mean scores of the students taught with conceptual change texts oriented instruction accompanied with analogies and students taught with traditionally designed chemistry instruction in terms of understanding chemical bonding concepts when their science process skills are controlled as a covariate.

$H_0 2$: There is no significant difference between the posttest mean scores of males and females in terms of understanding chemical bonding concepts when their science process skills are controlled.

$H_0 3$: There is no significant effect of interaction between gender difference and treatment on students' understanding of chemical bonding concepts.

$H_0 4$: There is no significant contribution of students' science process skills to understanding of chemical bonding concepts.

$H_0 5$: There is no significant mean difference between post-test mean scores of students taught with conceptual change texts oriented instruction accompanied with analogies and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject.

$H_0 6$: There is no significant difference between post-test mean scores of males and females with respect to their attitudes toward chemistry as a school subject.

$H_0 7$: There is no significant effect of interaction between gender difference and treatment with respect to their attitudes toward chemistry as a school subject.

# CHAPTER IV

# DESIGN OF THE STUDY

In this study, the quasi-experimental design was used (Gay, 1987). The random assignment of already formed classes to experimental and control groups was employed to examine treatment effect. Intact classes were used because it would have been too disruptive to the curriculum and too time consuming to have students out of their classes for treatment. In addition, due to administrative rules the classes were chosen randomly not students.

## 4.1 The Experimental Design

**Table 4.1** Research design of the study

| Groups | Pre-test | Treatment | Post-test |
|---|---|---|---|
| EG | CBCT<br>ASTC<br>SPST | CCTIA | CBCT<br>ASTC |
| CG | CBCT<br>ASTC<br>SPST | TDCI | CBCT<br>ASTC |

In this table, EG represents the Experimental Group instructed by conceptual change texts accompanied with analogies. CG represents the Control Group receiving traditionally designed chemistry instruction. CBCT is Chemical Bonding Concepts Test. CCTIA is Conceptual Change Text Oriented Instruction Accopmpanied With Analogies and TDCI is Traditionally Designed Chemistry Instruction. SPST refers to Science Process Skill Test. ASTC represents Attitude Scale Toward Chemistry.

### 4.2 Subjects of the Study

The subjets of this study consisted of 41 ninth grade students (20 male and 21 female) from two intact classes of a Chemistry Course from TED Ankara High School taught in the 2003-2004-spring semester. Two instruction methods used in the study were randomly assigned to groups. The data analyzed for this research were taken from 21 students participating instruction based on conceptual change texts oriented instruction accompanied with analogies and 20 students participating in the traditionally designed chemistry instruction.

### 4.3 Variables

#### 4.3.1 Independent Variables:

The independent variables in this study were two different types of treatment; conceptual change texts oriented instruction accompanied with analogies and traditionally designed chemistry instruction, gender and science process skill.

#### 4.3.2 Dependent Variables:

The dependent variables were students' understanding of chemical bonding concepts and their attitudes toward chemistry as a school subject.

### 4.4 Instruments

#### 4.4.1 Chemical Bonding Concepts Test (CBCT):

This test was developed by the researcher. The English version of the test was prepared because the language of instruction in Chemistry Course that include chemical bonding subject was in English at TED High School. The content was determined by examining textbooks, instructional objectives for the chemical bonding unit and related literature. During the developmental stage of the test, the instructional objectives of chemical bonding unit were determined (see Appendix A) to investigate whether the students achieved the behavioral objectives of the present study. The test included 21 items based on the two-tier multiple-choice format described by Haslam and Treagust (1987). The first tier of each item examined the content knowledge with two, three or four alternatives. The second tier consists of four reasons for the first tier. These reasons include one scientifically acceptable answer supporting the desired content knowledge in the first tier and three misconceptions identified from the literature related to students' misconceptions with respect to chemical bonding concepts (Butts and Smith, 1987; Tan and Tragust, 1999; Birk and Kurtz, 1999; Coll and Taylor, 2001; Nicoll, 2001) and opinions of chemistry teachers. A students' answer to an item was considered correct if the students selected both the correct content choice and the correct reason. For the content validity, each item in the test was examined by a group of experts in science education, chemistry and by the classroom teachers.

The reliability coefficient computed by Cronbach alpha estimates of internal consistency of this test was found to be 0.73, when both parts of the items were analyzed. This test was given to students in both groups as a pre-test to control students' understanding of chemical bonding concepts at the beginning of the instruction. It was also given to both groups as a post-test to compare the effects of two instructions (CCTIA & TDCI) on understanding of chemical bonding concepts. (See Appendix D).

**Table 4.2** Students' Misconceptions in Chemical Bonding

| **Bonding:** |
|---|
| **1.** Bonds are material connections rather than forces. |
| **2.** Bonds are only formed between atoms that donate \ accept electrons |
| **3.** Breaking chemical bond release energy. |
| **4.** Metals and nonmetals form molecules. |
| **5.** Atoms of a metal and a nonmetal share electrons to form molecules. |

| |
|---|
| **Table 4.2** Continued |
| **6.** Molecules forms from isolated atoms. |
| **7.** Bonding must be either ionic or covalent |
| **8**. Ions interact with the counter ions around them, but for those not ionically bonded these interactions are just forces. |
| **9.** The atomic electronic configuration determines the number of ionic bonds formed. |
| **10.** Number of covalent bonds formed by a nonmetals equal to the number of electrons in the valance shell. |
| **11.** Students have trouble discriminating between molecules that could or could not hydrogen bond. |
| **12.** Delocalized bonding (resonance) can be misinterpreted. |
| **13.** Metals do not have any bonds since all atoms are the same. |
| **14.** Metals have covalent and/or ionic bonding. |
| **15.** Metallic bonding exists between two different metal atoms**.** |
| **Octet Rule:** |
| **16.** Nitrogen atoms can share five electron pairs in bonding. |
| **17.** Atoms are bonded together to fill their octets. |
| **Bond Polarity:** |
| **18.** Ionic charges determine the polarity of the bond. |
| **19.** The polarity of a bond is dependent on the number of valance electrons in each atom involved in the bond. |
| **20.** Equal sharing of the electron pair occurs in all covalent bonds so that all covalent bonds are nonpolar |
| **21.** Largest atom exerts the greatest control over the shared electron pair. |
| **Polarity and Shape of Molecules:** |
| **22.** Polar molecules form when it has polar bonds |
| **23.** Presence of nonbonding electrons determines the resultant polarity of a molecule. |
| **24.** Nonpolar molecules form when the atoms in the molecule have similar electronegativities |

| **Table 4.2** Continued |
|---|
| **25.** Bond polarity determines the shape of a molecule. |
| **26.** The shape of a molecule is due to equal repulsion between the bonds only. |
| **27.** Only nonbonding electron pairs influenced the shape of the molecule. |
| **Intermolecular Forces:** |
| **28.** Intermolecular forces are forces within a molecule. |
| **29.** Strong intermolecular forces exist in a continuous covalent (network) solid. |
| **30.** Intramolecular covalent bonds are broken when a substance change phase. |
| **31.** Molecular solids consist of molecules with weak covalent bonding between the molecules. |
| **Structure of NaCl:** |
| **32.** NaCl exists as a molecule and these molecules are held together by covalent bonds. |
| **33.** Na and Cl atoms are bonded covalently but the ionic bonds between these molecules produced the crystal lattice. |
| **34.** $Na^+Cl^-$ bonds are not broken in dissolving. |
| **Electrical conductivity of graphite:** |
| **35.** There are " free" carbon atoms in graphite that move about and are responsible for conducting electricity. |
| **36.** The movement of the layers of atoms in graphite gives rise to its electrical conductivity. |

Based upon these misconceptions, taxonomy was constructed (see Table 4.3).

**Table 4.3** Taxonomy of Students' Misconceptions in Chemical Bonding

| MISCONCEPTION | ITEM |
|---|---|
| **Bonding** | 3, 10, 12, 18, 21 |
| **Octet Rule** | 9, 11 |
| **Bond Polarity** | 2, 13 |
| **Polarity and Shape of Molecules** | 6, 7, 8, 14, 19 |
| **Intermolecular Forces** | 1, 4, 16, 17, 20 |
| **Structure of NaCl** | 3, 15 |
| **Electrical conductivity of graphite** | 5 |

### 4.4.2 Attitude Scale Toward Chemistry (ASTC)

This scale was previously developed by Geban et al. (1994) to measure student's attitudes toward chemistry as a school subject. This scale consisted of 15 items in 5-point likert type scale (strongly agree, agree, undecided, disagree, strongly disagree). The reliability was found to be 0.83. This test was given to students in both groups before and after the treatment (see Appendix B).

### 4.4.3 Science Process Skill Test (SPST)

Okey, Wise and Burns (1982) developed this test. It was translated and adapted into Turkish by Geban et.al. (1992). This test contained 36 four-alternative multiple-choice questions. It was given to all students in the study. The reliability of the test was found to be 0.85. This test measured intellectual abilities of students related to identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations and graphing and interpreting data (see Appendix C).

### 4.4.4 Interview Questions

After the application of CCTIA and TDCI, interviews were prepared related to students' misconceptions obtained from post-test results. Four students from the experimental group and four students from the control group were selected based on achievement after their Chemical Bonding Concept Test scores. Students were randomly selected who were middle achiever. These students participated in 40 minutes semi-structured interview schedule designed to elucidate their beliefs and misconceptions about the concept of chemical bonding. The schedule was left flexible to allow students to express themselves in relative freedom and to enable the interviewer to ask thought-provoking questions. Interview questions focused following areas: (a) chemical bonding; (b) types of bonds (intramolecular and intermolecular); (c) structure of NaCl; (d) molecules and atoms; (e) electrical conductivity of graphite (see Appendix G). Researcher conducted interview.

### 4.4.5 Students Opinion About Use of Texts and Analogies

Two open-ended questions were asked to determine students' ideas about usage of conceptual change texts and analogies. Four students from the experimental group randomly selected who were middle achievers. Some examples of students' opinions are presented in Appendix I.

## 4.5 Treatment

This study was conducted over approximately eight weeks during the 2003-2004-spring semester and two ninth grade chemistry science classes in TED High School were enrolled. One of the classes was assigned as the experimental group instructed through the conceptual change texts accompanied with analogies, and the other group was assigned as the control group instructed through traditional instruction. Both groups were instructed on the same content of the chemistry course. The classroom instruction of the groups was three 40-minute sessions per week. All classes were instructed by the classroom teacher. The teacher had experience in conceptual change text and analogy instruction. The topic related to chemical bonding concept was covered as a part of the regular curriculum in the chemistry schedule course. The topics covered were the definition of a bond, types of bonds, polarity of bonds and molecules, definition of molecule, and definition of electron pair repulsion theory.

At the beginning, both groups were administered CBCT to determine whether there was any difference between the two groups with respect to understanding of chemical bonding prior to instruction. Also, ASTC was distributed to measure students' attitudes toward chemistry as a school subject. SPST was given to all students in the study to assess their science process skills.

In the control group, the teacher used lecture and discussion methods to teach chemical bonding concepts and employed proportional reasoning techniques, probably coupled with algorithmic approaches in problem solving. Also, teacher strategies were dependent on teacher exploration without consideration of students' misconceptions.

Students in the experimental group worked with the conceptual change texts accompanied with analogies through teacher lecture. They received three certain conceptual change texts related to misconceptions listed in table 4.2. The main aim of the preparation of conceptual change texts was to suggest conditions in which misconceptions can be replaced into scientific conceptions. So, conceptual change texts were constructed by use of Posner et al.'s (1982) conceptual change model. Firstly, students were asked questions to make them aware of their naïve conceptions. Students were allowed to discuss these questions in the conceptual change text by using their previous knowledge related to chemical bonding concepts. During discussions, they had cognitive conflict when their ideas were not adequate to answer these questions and they dissatisfied with their existing conceptions. This situation supported the first condition of Posner et al.'s (1982) model. Then, students were informed about probable misconceptions. After that, a scientific correct explanation of the situations was given. Since chemical bonding is an abstract topic, analogies and daily life examples were used to explain the concept in the conceptual change texts. Posner et.al. (1982) also used analogies and examples to presented scientifically correct explanation in his conceptual change model. He gave the big importance to analogies to enhance understanding. For example, while explaining what a chemical bond was, he constructed similarities between magnets and bonds; the fact that like poles repel each other and unlike poles attract each other is similar to the attraction and repulsion between electric charges. Also, borrowing books from the library was given as an example for covalent bonding; although the books are given to a person, at the same time they belong to the library. In this step, we tried to accomplish Posner et al.'s (1982) conditions of intelligibility and plausibility by stressing on the students' preconceptions, making relationship between their conceptions and scientific knowledge and giving examples. Finally, it was suggest students to replace or integrate the newly learned concepts with their existing conceptions. Moreover, students saw usage of information they obtained in explaining other situations. Therefore, Posner et al.'s (1982) last condition (fruitfulness) was also achieved. Before presenting each new concept, the teacher asked questions which students could answer by using their previous knowledge. Some questions were: Why does chemical bond occur? Why molecular solids have high viscosity? Why does table salt conduct electricity when dissolved in water? Why are metals shiny and ductile? All of the questions reflected students' misconceptions in chemical bonding concepts. An example of conceptual change text is presented in Appendix E.

Homework questions were also used in the first conceptual change text. The main aim of the preparation of these questions was to point out students to the limitations of analogy and to decrease the possibility that the analogy may lead to misconceptions. Because, most students wrongly think that there is a 1:1 correspondence between analogies and reality and they are not aware of the points at which analogies breaks down. For this reason, firstly the definitions and examples of the analogies were given to the students. And, students discuss the limitations of these analogies with their teacher, as in the work of Osborne (1983). Also, the shared and unshared points of given analogies with real model were written in the conceptual change texts. Then, homework questions were given to the students. Some of these questions asked the related (shared and unshared) points of analogies with reality, and some questions asked to students create analogies for real model. All of the answers of students were discussed in the classroom. Because, the use of classroom discussions of analogies has been advocated as a way to increase awareness of their limitations and encourage critical thinking (Webb, 1985). Examples of students' answers to homework questions are presented in Appendix H.

At the end of the treatment, all students were given CBCT as a post-test. They were also administered ASTC.

### 4.6 Analysis of Data

In this study, ANCOVA was used to determine effects of two different instructional methods related to chemical bonding concepts by controlling the effect of students' science process skills as a covariant. Also this statistical technique revealed the contribution of science process skills to the variation in understanding and the effect of gender difference on students' understanding chemical bonding concepts. To test the effect of treatment on students' attitudes toward chemistry as a school subject and the gender effect on students' attitudes toward chemistry, two-way ANOVA was used.

### 4.7 Assumptions and Limitations

#### 4.7.1 Assumptions:

1. All the students in both groups were accurate and sincere in answering the questions of measuring instruments.
2. The teacher who applied this study was not biased during the treatment.
3. There was no interaction between groups.

#### 4.7.2 Limitations:

1. This study was limited to the unit of "Chemical bonding".
2. The subjects of the study were limited to 41 ninth grade students from TED Ankara High School.

# CHAPTER V

# RESULTS AND CONCLUSIONS

## 5.1 Results

The hypotheses stated in Chapter 3 were tested at a significance level of $\alpha=0.05$. Analysis of covariance (ANCOVA) and analysis of variance (ANOVA) were used to test the hypotheses. In this study, statistical analyses were carried out by SPSS/PC (Statistical Package for Social Sciences for Personal Computers) (Noruis, 1991).

The analysis showed that there was no significant difference at the beginning of the treatment between the CCTIA group and the TDCI group in terms of students' understanding of chemical bonding concepts ($t = 0.53$, $p>0.05$) and students' attitudes toward chemistry ($t = 0.77$, $p >0.05$) and their science process skills ($t = 1.72$, $p >0.05$)

**Hypothesis 1:**

To answer the question posed by hypothesis 1 stating that there is no significant difference between the post-test mean scores of the students taught by CCTIA and those taught by TDCI with respect to understanding chemical bonding concepts when science process skill is controlled as a covariate, analysis of covariance (ANCOVA) was used. The measures obtained are presented in Table 5.1.

**Table 5.1** ANCOVA Summary (Understanding)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Covariate (Science Process Skill) | 1 | 53.839 | 53.839 | 12.144 | 0.002 |
| Treatment | 1 | 28.139 | 28.139 | 6.347 | 0.018 |
| Gender | 1 | 7.434 | 7.434 | 1.677 | 0.206 |
| Treatment*Gender | 1 | 45.328 | 45.328 | 10.224 | 0.003 |
| Error | 29 | 128.570 | 4.433 | | |

The result showed that there was a significant difference between the post-test mean scores of the students taught by CCT&AI and those taught by TDCI with respect to the understanding of chemical bonding concepts. The CCT&AI group scored significantly higher than TDCI group
($\overline{X}$ (CCT&AI) = 9.35, $\overline{X}$ (TDCI) = 6.29).

Figure 5.1 shows the proportions of correct responses to the questions in the post-test for two groups.

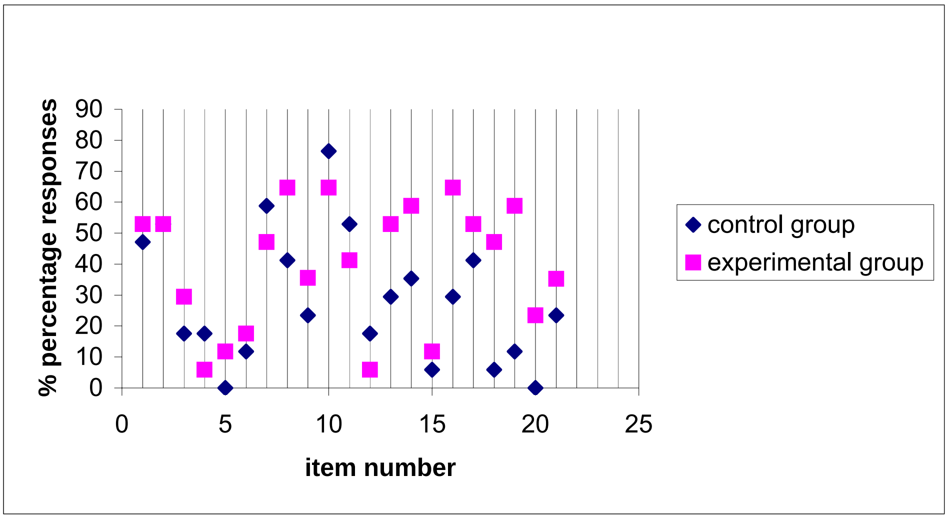



**Figure 5.1** Comparison between post-test scores of CCTIA group and that of TDCI group.

As seen in the figure there was a difference in responses between the two groups to the items in CBCT. Poorer student results were obtained for questions 5, 8, 13, 14, 16, 18, 19 and 20 in the TDCI group. Question 5 was related to electrical conductivity of graphite. Both groups showed low achievement for this question. None of the students in the TDCI group gave correct answer to the two parts of this question whereas 11.8% of the students in the CCTIA group answered it correctly stating that only three of the four valance electrons in an atom of carbon in graphite are involved in bonding and the fourth electron being delocalised within the layers of atoms, giving rise to its electrical conductivity. Among control group students, the common misconceptions were that electrons escape from the covalent bonds in graphite and are free to move within the molecule (41.2%). And, most of the experimental group students thought that graphite could conduct electricity because it has layers of carbon atoms (41.2%). This might because they were taught that mobile electrons and ions conduct electricity and therefore the layers of atoms could also electricity because they could move. The percentages of experimental and control group students' selection of alternatives in the posttest are given below:

**Table 5.2** Percentages of students' selection of alternatives for item 5

| **Graphite can conduct electricity because it has <u>delocalised</u> electrons.**<br><br>***(I)** True **(II)** False<br><br>**Reason** | **Percentage of students' responses (%)**<br>**Experimental Group** | <br>**Control Group** |
|---|---|---|
| ***Alternative A**<br>Only three of the four valance electrons of a carbon atom are involved in bonding and the fourth electron is delocalised. | 11.8 | 5.9 |
| **Alternative B**<br>Electrons escape from the covalent bonds in graphite and are free to move within the molecule. | 0 | 41.2 |
| **Alternative C**<br>Graphite can conduct electricity because it has layers of carbon atoms, which can slip over each other. | 41.2 | 23.5 |

| | | |
|---|---|---|
| **Alternative D**<br>Graphite can conduct electricity because in graphite, some carbon atoms are delocalised and they conduct electricity. | 35.3 | 23.5 |

* Correct alternative

In question 8, students were asked first to select the correct purpose of using “electron pair repulsion theory”. Before treatment, 58.8% of the experimental students responded this part correctly after treatment, in the experimental group, 82.4% of the students answered the first part of the question correctly. For the second part of the same question, majority of the experimental group students 64.7% group answered this part correctly whereas only 47.1% of the students in the control group answered it correctly after treatment. In the experimental group, 64.7% of the students gave correct answer for the two parts of the question whereas only 41.2% of the students in the control group responded to the two parts correctly. Among control group students, the common misconceptions were that “electron pair repulsion theory”states that the shape of the molecule is due to repulsion between the atoms in the molecule (23.5%). The misconceptions that this item measured and the percentages of experimental and control group students’ selection of alternatives in the posttest are given below:

**Table 5.3** Percentages of students’ selection of alternatives for item 8

| **The ‘’electron pair repulsion theory’’ is used to determine the**<br>(I) polarity of a molecule<br>*(II) shape of a molecule | **Percentage of students’ responses (%)** | |
|---|---|---|
| **Reason** | **Experimental Group** | **Control Group** |
| **Alternative A**<br>Nonbonding electrons determine the polarity of the molecule. | 17.6 | 17.6 |
| ***Alternative B**<br>The theory states that the shape of the molecule is due to the arrangement of the bonding and nonbonding electron pairs around the central atom to minimize electron repulsion. | 64.7 | 47.1 |

| | | |
|---|---|---|
| **Alternative C**<br>The theory states that the polarity of the molecule is dependent on the number of polar bonds present. | 5.9 | 5.9 |
| **Alternative D**<br>The theory states that the shape of the molecule is due to repulsion between the atoms in the molecule**.** | 5.9 | 23.5 |

[*] Correct alternative

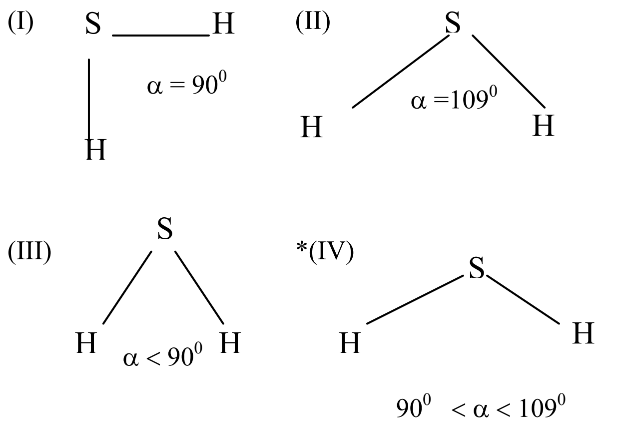
Question 13 was related to the polarity of covalent bond polarity between chloride and fluorine. Before treatment, 23.5% of the experimental group students and 17.6% of the control group students responded correctly to this question. After treatment, 52.9% of the students taught by the CCTIA and, 29.4% of the students taught by the TDCI seemed to be comfortable with the right idea that the bond between chloride and fluorine is polar covalent bond because the electronegativity of two atoms is different. The common misconception was that all covalent bonds are nonpolar. Taber (2003) claims the reason for this misconception is that use of the term “electron sharing” in covalent bonding causes students to interpret it in its social meaning thus they imply that equal sharing occurs and cannot conceptualize polar bonds. The misconceptions that this item measured and the percentages of experimental and control group students’ selection of alternatives in the posttest are given below:

**Table 5.4** Percentages of students' selection of alternatives for item 13

| **In ClF molecule, the bond between Chloride and Fluorine is**<br><br>*(I) polar covalent bond<br>(II) nonpolar covalent bond<br><br>Reason | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experimental Group** | **Control Group** |
| **Alternative A**<br>Chlorine and Fluorine are negatively charged in their compounds. There is not any ionic bond between them. That is, bond is 100 % covalent. | 11.8 | 35.3 |
| ***Alternative B**<br>The electronegativity of two atoms is different. | 47.1 | 47.1 |
| **Alternative C**<br>Both atoms join to Cl-F bond with one each electron | 35.3 | 0 |
| **Alternative D**<br>Cl has more electron than F.<br>* Correct alternative | 0 | 11.8 |

A similar difference between CCTIA group and TDCI group was also obtained for item 14. After treatment, 58.8% of the students taught by the CCTIA and, 35.3% of the students taught by the TDCI responded correctly to this question. In the first part of this question, students were asked to the following question: "What is the bond angle of the $H_2S$ molecule?" Before instruction, 35.3% of the experimental groups students gave correct response to the first part of the question and 11.8% responded correctly to the second part of the same question. After instruction 64.7% of the students in this group answered correctly in the first part, and 76.5% of the students gave right answer in the second part. The common misconception was that students did not consider the influence nonbonding electron pairs have on the shape of a molecule. Table 5.5 presents the percentages of experimental and control group students' selection of alternatives in the post-test:

**Table 5.5** Percentages of students' selection of alternatives for item 14

| What is the bond angle of the $H_2S$ molecule? | Percentage of students' responses (%) | |
|---|---|---|
|   | **Experimental Group** | **Control Group** |
| **Reason** | | |
| **Alternative A**<br>Angle between $sp^3$ orbital is approximately $109^0$. | 0 | 17.6 |
| ***Alternative B**<br>Angle between $sp^3$ orbital is approximately $109^0$ and nonbonding electrons on S affect the bond angle | 76.5 | 47.1 |
| **Alternative C**<br>Angle between p orbital is $90^0$. | 0 | 5.9 |
| **Alternative D**<br>Angle between p orbital is $90^0$ and nonbonding electrons on S affect the bond angle. | 17.6 | 17.6 |

* Correct alternative

For question 16, 64.7% of the students in the CCTIA group stated correctly that there are Van der Waals forces between $H_2$ molecules in liquid state. However, 29.4% of the students in the TDCI group answered the same question correctly. 23.5% of the control group students stated that there are no attractive forces between the $H_2$ molecules in the liquid hydrogen. In Table 5.6, the percentages of experimental and control group students' selection of alternatives in the post-test are presented:

**Table 5.6** Percentages of students' selection of alternatives for item 16

| **Hydrogen is liquid at low temperatures. Are there any attractive forces between $H_2$ molecules in the liquid hydrogen?** *(I) Yes (II) No **Reason** | **Percentage of students' responses (%)** **Experimental Group** | **Control Group** |
|---|---|---|
| **Alternative A** There is no electron transferring or sharing between Hydrogen molecules to form attractive force. | 5.9 | 23.5 |
| **Alternative B** Particles in $H_2$ are uncharged. | 11.8 | 11.8 |
| **Alternative C** There is a massive interaction between the particles**.** | 11.8 | 17.6 |
| ***Alternative D** There are Van der Waals Forces between molecules. | 64.7 | 41.2 |

* Correct alternative

In item 18, students were asked first to whether NaCl exist as a molecule or not at room temperature. After treatment, 70.6% of the experimental group students and 41.2% of the control group students answered the first part of the question correctly. For the second part of the same question, majority of the experimental group students (52.9%) group answered this question correctly whereas only 23.5% of the students in the control group answered it correctly after treatment. In the experimental group, 47.1% of the students gave correct answer for the two parts of the question whereas only 5.9% of the students in the control group responded to the two parts correctly. According to Taber (1994), this misconception can be arising from the way ionic bonding is presented in the classroom. Teachers illustrate ionic bonding by drawing the transfer of an electron from a sodium atom to a chlorine atom to from a positive sodium ion and a negative chlorine ion. They point to the pair of ions and say that strong electrostatic forces attract the sodium and chlorine ions. Thus the picture of a discrete unit of sodium chloride can be implanted in the minds of the students. The misconceptions that this item measured and the percentages of experimental and control group students' selection of alternatives in the posttest are given below:

**Table 5.7** Percentages of students' selection of alternatives for item 18

| **At room temperature, sodium chloride, NaCl, exist as a molecule**<br><br>**(I)** True ***(II)** False<br><br>**Reason** | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experimental Group** | **Control Group** |
| **Alternative A**<br>The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule. | 17.6 | 17.6 |
| **Alternative B**<br>After donating its valance electron to the chlorine atom, the sodium ion forms a molecule with the chlorine ion. | 11.8 | 41.2 |
| ***Alternative C**<br>Sodium chloride exists as a lattice consisting of sodium ions and chloride ions. | 52.9 | 23.5 |
| **Alternative D**<br>Sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms | 11.8 | 11.8 |

* Correct alternative

A similar difference between CCTIA group and TDCI group was also obtained for item 19. In the experimental group, 58.8 % of the students gave correct answer for the two parts of the question whereas only 11.8% of the students in the control group responded to the two parts correctly. This question was related to the polarity of molecules. Two misconceptions were found among control group students. The first one, selected by 23.5% of control group students, identifies nonpolar molecules as those formed only between atoms of similar electronegativities. The second misconception, selected by 23.5% of control group students, identifies the presence of polar bond is a factor in determining the resultant polarity of a molecule. Generally, students with these views did not consider the two factors of shape and bond polarity when determining bond polarity of a molecule. Table 5.8 presents the percentages of experimental and control group students' selection of alternatives in the post-test:

**Table 5.8** Percentages of students' selection of alternatives for item 19

| **What can be said about the polarities of $CCl_4$ and $CHCl_3$?**<br>(I) Both of them are polar<br>(II) Both of them are nonpolar<br>*(III) One of them is polar and the other one is nonpolar<br><br>**Reason** | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experimental Group** | **Control Group** |
| **Alternative A**<br>A molecule is nonpolar, only if atoms of molecule have same electronegativities. | 5.9 | 23.5 |
| **Alternative B**<br>If molecule has tetrahedral shape, it is nonpolar. | 17.6 | 17.6 |
| **Alternative C**<br>If molecule contains polar bonds it is a polar molecule | 5.9 | 23.5 |
| ***Alternative D**<br>Polarity of molecule depends on the polarity of its bonds and shape of the molecule. | 64.7 | 29.4 |

* Correct alternative

Question 20 was related to Van der Waals Forces. Both groups showed low achievement for this question. None of the students in the TDCI group gave correct answer to the two parts of this question whereas 23.5% of the students in the CCTIA group answered it correctly. Among control group students, the common misconceptions were that because iodine has more protons, its nuclei pull electrons more strongly than the others, so chlorine ($Cl_2$) is gas, bromine ($Br_2$) is liquid, and iodine ($I_2$) is solid at room temperature (41.2%). The percentages of experimental and control group students' selection of alternatives in the posttest are given below:

**Table 5.9** Percentages of students' selection of alternatives for item 20

| **Cl, Br and I elements are in 7A group. They found in nature as diatomic and show similar chemical properties. What is the reason that Chlorine ($Cl_2$) is gas, Bromine ($Br_2$) is liquid, and Iodine ($I_2$) is solid at room temperature?**<br><br>(I) Cl-Cl, Br-Br and I-I bond have not equal strength.<br>*(II) $Cl_2$, $Br_2$, and $I_2$ molecules have different numbers of electrons.<br>(III) Electronegativity of Chloride, Bromine and Iodine are different from each other.<br><br>**Reason** | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experimental Group** | **Control Group** |
| ***Alternative A**<br>The attractive forces between the $I_2$ molecules, which have more electrons among them, are stronger than the others. | 52.9 | 17.6 |
| **Alternative B**<br>The most electronegative one is Cl. Electronegative atoms are more active so Cl moves faster and it is in gas state. | 17.6 | 5.9 |
| **Alternative C**<br>Because Iodine has more protons, its nuclei pull electrons more strongly than the others. | 17.6 | 41.2 |
| **Alternative D**<br>I-I covalent bond is stronger than the others so $I_2$ is in solid state at room temperature. | 5.9 | 23.5 |

* Correct alternative

For these questions causing striking difference, the difference between the percentages of students' correct responses in the pre-test and the percentages of students' correct responses in the post-test was striking:

**Table 5. 10** Percentages of students' correct responses in the pre-test and post-test for selected items

| Item | Experimental Group | | Control Group | |
|---|---|---|---|---|
| | Pre-test (%) | Post-test (%) | Pre-test (%) | Post-test (%) |
| 5 | 11.8 | 11.8 | 5.9 | 0 |
| 8 | 29.4 | 64.7 | 35.3 | 41.2 |
| 13 | 23.5 | 52.9 | 17.6 | 29.4 |
| 14 | 5.9 | 58.8 | 23.5 | 35.3 |
| 16 | 35.3 | 64.7 | 11.8 | 29.4 |
| 18 | 5.9 | 47.1 | 17.6 | 5.9 |
| 19 | 17.6 | 58.8 | 0 | 11.8 |
| 20 | 0 | 23.5 | 0 | 0 |

It can be seen that there is an increase in the percentage of correct response in the experimental group. More students in the experimental group removed their misconceptions after instruction than students in the control group. The experimental and control group students' correct response percentages of each question in the CBCT is presented in Appendix F.

**Hypothesis 2:**

To answer the question posed by hypothesis 2 that states that there is no significant difference between the posttest mean scores of males and females in their understanding of chemical bonding concepts, analysis of covariance (ANCOVA) was run. Table 5.1 also gives the effect of gender difference on the understanding of chemical bonding concepts. The findings revealed that there was no significant mean difference between male and female students in terms of understanding chemical bonding concepts ($F = 1.68$; $p > 0.05$). The mean post-test scores were 6.82 for males and 8.82 for females.

**Hypothesis 3:**

To test hypothesis 3, which states that there is no significant effect of interaction between gender difference and treatment with respect to students' understanding of chemical bonding concepts, analysis of covariance (ANCOVA) was used. Table 5.1 also gives the interaction effect on understanding of chemical bonding concepts. The findings revealed that there was a significant effect of interaction between gender difference and treatment on students' understanding of chemical bonding concepts ($F = 10.22$; $p < 0,05$). This interaction came from the difference between boys and girls in each group separately. In experimental group, there was a significant difference between post-test mean scores of boys and girls in the favour of girls ($t= 2.88$, $p<0.05$). Also, in the control group, there was a significant difference between post-test mean scores of boys and girls in the favour of boys ($t= 2.25$, $p<0.05$).

**Hypothesis 4:**

To analyze hypothesis 4 that states that there is no significant contribution of students' science process skills to understanding of chemical bonding concepts, analysis of covariance (ANCOVA) was used. Table 5.1 also represents the contribution of science process skill to the understanding of chemical bonding concepts. F value indicated that there was a significant contribution of science process skills on students' understanding of chemical bonding concepts ($F = 12.144$; $p < 0.05$).

**Hypothesis 5:**

To answer the question posed by hypothesis 5 which states that there is no significant difference between post-test mean scores of the students taught with instruction based on conceptual change texts instruction accompanied with analogies and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject, two-way analysis of variance (ANOVA) was used. Table 5.11 summarizes the result of this analysis.

**Table 5.11** ANOVA Summary (Attitude)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment | 1 | 14.761 | 14.761 | 0.281 | 0.600 |
| Gender | 1 | 12.879 | 12.879 | 0.245 | 0.624 |
| Treatment*Gender | 1 | 2.852E-02 | 2.852E-02 | 0.001 | 0.982 |
| Error | 30 | 1574.152 | 52.472 | | |

The results showed that there was no significant difference between post-test mean scores of the students taught through instruction based on conceptual change texts instruction accompanied with analogies and traditionally designed chemistry instruction with respect to attitudes toward chemistry as a school subject.

**Hypothesis 6:**

To test hypothesis 6, which claims that there is no significant difference between post-attitude mean scores of males and females, two-way analysis of variance (ANOVA) was run. Table 5.11 also shows the effect of gender difference on students' attitudes. It was found that there was no significant difference between post-test mean scores of males and females with respect to attitudes toward chemistry as a school subject.

**Hypothesis 7:**

To test hypothesis 7, which states that there is no significant effect of interaction between gender difference and treatment with respect to students' attitudes toward chemistry as a school subject, two-way analysis of variance (ANOVA) was used. Table 5.11 also gives the interaction effect on understanding of chemical bonding concepts. The findings revealed that there was no significant effect of interaction between gender difference and treatment on students' attitudes toward chemistry as a school subject.

### 5.2 Interviews

In this study, interviews were applied to eight students of the 9th grades in TED Ankara High School to investigate the students' knowledge of chemical bonding and the existence of any misconceptions. Four students from the experimental group and four students from the control group were selected based on achievement after their Chemical Bonding Concepts Test scores. Students from each group were randomly selected who were middle achiever. Students 1-4 were from control group and students 4-8 were from the control group. Selected examples of excerpts from interviews are given below:

*Students' ideas about chemical bonding*

*Interviewer: "… what are the chemical bonds? What does the term "chemical bond" mean to you?*

*Student 1: " Chemical bonds are the bonds between the atoms. These bonds make the substance solid, liquid, or gas related to their strength."*

*Interviewer: "… How many chemical bonds do you know?*

*Student 1: "Um...Three "*

*Interviewer: "… What are they?*

*Student 1: Ionic bond, chemical bond and metallic bond.*

*Student 2: " When someone says "chemical bond"...umm. Firstly I think of ionic and covalent bonding........ The hybridization related with this term.*

*Interviewer: Can you give an example for a chemical bonding?*

*Student 2: Think of many chemical substances like* $H_2$*,* $H_2O$ *etc."*

*Student 5: "It is the bond between or within molecules"*

*Student 6:"It forms an image of two or more substances held together by unseen forces, in my mind. And, hm, I get the idea that these forces are rather strong ......and they require energy to be broken."*

*Interviewer: Can you give an example for a chemical bonding?*

*Student 6:" I'm not sure whether intermolecular bonds are chemical bonds, but I think Van der Waals forces, Ionic bonds, covalent bonds, network covalent bonds can be an example for chemical bonds.*

Students' responses to the questions revealed that students in both groups do not have an accurate chemical bond definition in their mind. In addition, they do not have enough conceptual knowledge about the types of chemical bonding.

*Electrical conductivity of graphite*

*Interviewer: Could you please explain why graphite conducts electricity?*

*Student 8: I'm not very sure but I'll try to guess. Um.. Graphite has pi bonds in addition to the sigma bonds so it is not so stable as diamond. This may be causing the free movement of electrons.*

*Student 7: It is in network covalent structure so there are layers of carbon...Maybe those layers slide over each other for it to help conduct electricity.*

*Student 1: I don't know. I never thought about that before.*

*Student 4: Because of the structure of graphite.....because it has disordered geometry.*

These answers showed that students in control group did not understand the concept of delocalization of electrons in graphite. Moreover, half of the students in experimental group could not explain the reason of electrical conductivity of graphite exactly. They believed that the movement of the layers of atoms in graphite gives rise to its conductivity. This might because they were taught that mobile electrons and ions conduct electricity and therefore the layers of atoms could also electricity because they could move.

*Molecules and Atoms*

*Interviewer: Could you please compare the arrangement of the water ($H_2O$) "molecules in water and stream" in a boiling kettle by drawing?*

*Student 3:*

*burçak*

*Student 4:*

*ece*

*Student 7:*

*Çise*

Students' drawings show that the presence of misconceptions among control group students concerning the particle nature of mater. Most of the students in control group held the misconception that intramolecular covalent bonds (instead of intermolecular bonds) are broken when a substance change phase. And the others thought that bonds do not broken, when substance change its state.

*Octet Rule*

*Interviewer: Could you please draw the shape of the nitrogen bromine molecule?*

*Student 1:*

*burçak*

*Student 5:*

*çise*

*Interviewer: Why does the nitrogen bromine molecule adopt this geometry?*

*Student 1: Because nitrogen has two nonbonding electrons*

*Student 5: Because the unshared pair of electrons that nitrogen has cause a great deal of negative charges that pushes the three bromine atoms.*

These answers showed that most of the students could correctly predict the shape of the $NBr_3$. However, they have misconception in explaining the reason that why it adopt this geometry. Most of them considered that only the nonbonding electron pairs influence the shape of the molecule.

*The Structure of NaCl*

*Interviewer: Could you please draw the structure of sodium chloride (NaCl) and explain why you drew it that way?*

*Student 1:*

*Cansu ekin*

*Student 8:*

*Çise*

In control group, students believed that the sodium and chloride ions could only from one ionic bond each. Because they only memorized the definition of ionic bond given in the lesson, and they thought that ionic bond formed when atoms donate/accept electron. So it must be electron transfer between the atoms to ionic bonding occurs. However, experimental group students understand the reason of formation of ionic bond. And they believed that ionic bonds formed between atoms because of the attractive forces. This might because using different instructional strategies to explain this concept.

*Intermolecular force*

*Interviewer: The boiling point of $F_2$ is –188 $^oC$ and the boiling point of $Br_2$ is 58.8 $^oC$ . Therefore, Fluorine ($F_2$ ) is gas and Bromine ($Br_2$ ) is liquid at room temperature. Could you please explain the reason that this huge differences between the boiling points of $F_2$ and $Br_2$ molecules?*

*Student 2: Um... because if the atomic number increase boiling point increase....*

*Interviewer: Ok...Why boiling point of molecule is increased with atomic number?*

*Student 2: I have no idea.*

*Student 4: It might be result from the different types...but I don't know.*

*Student 7: The reason is that the atoms of fluorine and bromine are only held together by London Force. So the one with more electrons has a higher point of boiling, since London Dispersion Forces are based on the movement of electrons (the quantity is important).*

*Student 5: They have both London Forces, but $Br_2$ has more electrons. Because of this, it has a higher attraction and thus has a higher boiling point.*

In this interview, no one in the control group could give correct reason for explaining the differences between the boiling points of given molecules, whereas students in experimental groups easily could answer it. It might be resulted from using analogies and conceptual change texts in experimental group to teach this subject.

### 5.3 Conclusions

The following conclusions can be drawn from the results:

1. The CCTIA caused a significantly better acquisition of scientific conceptions related to chemical bonding and elimination of misconceptions than TDCI.

2. The CCTIA and TDCI developed the similar attitude toward science as a school subject

3. Science process skill had a significant contribution to the students' understanding of chemical bonding concepts.

4. There was no significant difference between female and male with respect to understanding of chemical bonding concepts and attitude towards chemistry as a school subject.

5. There was a significant effect of interaction between the gender and treatment on students' understanding of chemical bonding concepts.

# CHAPTER VI

# DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

## 6.1 Discussion

The major purpose of this study was to compare the effects of instruction based on conceptual change texts accompanied with analogies over traditionally designed chemistry instruction on ninth grade students' understanding of chemical bonding concepts.

In the light of the results obtained from analysis, it can be concluded that the instruction based on conceptual change texts accompanied with analogies approach caused a significantly better acquisition of scientific conceptions related to chemical bonding and elimination of misconceptions than traditionally designed chemistry instruction. That is, students in the experimental group showed higher performance than students in the control group instructed by traditionally designed chemistry instruction with respect to chemical bonding concepts.

The conceptual change text used in this study was designed according to Posner et al.'s (1982) instructional theory. This theory holds that learners must become dissatisfied with their existing conceptions as well as find new concepts intelligible, plausible, and fruitful, before conceptual restructuring will occur. In the experimental group, the main aim of the preparation of conceptual change texts was to activate students' prior knowledge and misconceptions and to help them to understand and apply the chemical bonding concepts through the use of explanations, analogies and examples. The other teaching technique was used in this study is analogy.  A number of studies have shown that analogies help students to learn difficult concepts and make science interesting (Hodgson, 1995). Also, Posner et al

(1982) used analogies to presented scientifically correct explanation in his conceptual change model. However, if students are not aware of the points at which analogy breaks down, it can be promote misconceptions. To reduce this danger, homework questions related with the limitations of analogies were given to the students and the answers of them were discussed in the classroom. In this way, the teacher increases the awareness of analogies' limitations and encourage to his students to critically thinking. At the end of the study, we administered interviews to 8 students (four of them from experimental and four of them from control group) in order to learn the reasons of their misconceptions even after administered treatments. Also, we asked two open-ended questions to four experimental group students to determine their ideas about usage of conceptual change texts and analogies. The answers of these questions showed that students believed that usage of conceptual change texts and analogies improve their understanding

On the other hand, traditionally designed chemistry instruction did not facilitate conceptual change because teacher strategies were dependent on teacher exploration without consideration of students' misconceptions and he used a lecture method in instruction. He wrote important notes to the board and distributed worksheets to the students to complete. That is, students in the control group were taught with traditionally designed chemistry instruction were passive listeners and they are not construct their knowledge whereas students in the experimental group were allowed to constructed their knowledge by using conceptual change approach. This might cause the difference in the concept tests scores of students in control and experimental groups

The degree of science process skills accounted for a significant portion of variation in science achievement. Because, it reflects one's intellectual ability to identify variables, identify and state the hypotheses, design investigations and graph and interpret data.

Also, this study investigated the effect of treatment (instruction based on conceptual change texts accompanied with analogies vs. traditionally designed chemistry instruction) on students' attitudes towards chemistry as a school subject. However, there is no differences are found. They developed the similar attitude toward science as a school subject.

Moreover, the results investigated that there is no differences between female and male students with respect to achievement related to chemical bonding concepts. This means that, there was no significant difference between male and female students who were instructed by instruction based on the conceptual change texts accompanied with analogies and those who were instructed through traditionally designed chemistry instruction. The reason why no significant difference was found in this study might be due to the fact that since the students had similar backgrounds or experience and they are generally familiar with learning subjects from texts or textbook

This study has shown that most of the students have misconceptions about chemical bonding concepts because they include abstract and theoretical concepts. If these misconceptions are not corrected, they affect further learning negatively. Therefore, teacher must identify students' misconceptions and find out to prevent them from occurring. Traditionally designed methods are not so effective in developing conceptual understanding of the subject matter and removing misconceptions. Because, students are passive in the traditional lecture method and they are not construct their knowledge. On the contrary, conceptual change text and analogy are the effective teaching strategies to dispel students' misconceptions and enhance understanding of chemical bonding concepts.

### 6.2 Implications

Results of the present study had some implications for science teachers, educators and the researchers. The findings of this study have the following implications:

1. Most of the students have difficulty in understanding chemical bonding concepts and hold several misconceptions because they include abstract and theoretical concept. And the existence of these misconceptions among students leads a serious obstacle to learning in chemistry. So, teachers must be aware of these misconceptions and try to prevent them from occurring.

2. Most of the misconceptions arise from the students' inability to use their prior knowledge in learning situations because students construct their knowledge by making links between their idea and new concepts. When teachers link new information to the student's prior knowledge, they activate the student's interest and curiosity, and infuse instruction with a sense of purpose. Therefore, teachers should take time to assess what their students have learned from prior experiences.

3. Teachers should ask questions that activates students' relevant prior knowledge and promotes meaningful learning. Also, they should be allowing to the students to discuss these questions. By this way, students may be realizing that their current ideas were not effective in explaining the situation take the new knowledge into account seriously.

4. Teachers must be prepare their lesson while giving importance to students' prior knowledge to make a necessary conceptual change on students' minds.

5. Students should build connections between daily life and their scientific conceptions

6. Teachers should be informed about the limitations of analogy, and they should be preventing them from occurring.

7. School administrators should encourage teachers to use conceptual change text and analogy in their lesson.

8. Curriculum programs should be based on the constructivist perspective and textbooks should be improved so that students' misconceptions can be minimized.

9. Teachers should be informed about the usage and importance of conceptual change approach.

10. Science process skill is a strong predictor of science achievement. Teacher should adjust their teaching strategies to develop students' science process skills.

11. Trained teachers on conceptual change approach should be model for other teachers.

12. Teachers should be aware of students' attitudes towards chemistry as a school subject and should seek ways to make students have positive attitudes.

13. Well-designed conceptual change text and analogy instruction can be used to remove misconceptions and facilitate conceptual change. Conceptual change texts create conceptual conflict with the existing knowledge and facilitate conceptual change. Also, analogies enhance the understanding by providing the visualizing

the abstract concepts, by helping compare the students' real world with new concepts and by increasing the students' motivation.

14. The theory of science conceptual change should be applied to science teacher education and research.

### 6.3 Recommendations

On the basis of the findings from this study, the researcher recommends that:

A study can be carried out for different grade levels and different science courses.

This study can be conducted with a larger sample size from different schools to get more accurate results and to search a generalization for Turkish student population.

Effectiveness of conceptual change texts and analogies can be compared with the other instructional methods such as learning cycle, problem solving or computer assisted instruction.

Similar research studies can be conducted to evaluate the effect of conceptual change approach on other learning outcomes such as logical thinking.

Further studies can be conducted to test the direct effects of the conceptual change texts and analogies separately on science achievement.

Computers can be used to teach the scientific concepts since they provide dynamic displays and visualizations, simulations and models.

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# APPENDIX A

## INSRTUCTIONAL OBJECTIVES

1. To define chemical bonding.
2. To explain why chemical bonding occurs.
3. To explain Lewis structure
4. To explain octet rule
5. To describe types of chemical bonds.
6. To differentiate between intermolecular and intramolecular bonds.
7. To explain ionic and covalent bonds.
8. To distinguish between ionic and covalent bonding.
9. To identify polarity.
10. To discriminate between polar and nonpolar covalent bonds.
11. To explain metallic bonding.
12. To express Van der Waals forces, dipole-dipole interactions and hydrogen bonding.
13. To explain structures of ionic and covalent compounds
14. To explain properties of ionic and covalent compounds.
15. To give examples for ionic and covalent compounds.
16. To estimate physical properties of compounds according to the type of bonds they have.
17. To estimate the shape of molecules.
18. To explain structures of Ionic Solids
19. To explain structures of Molecular Solids
20. To estimate type of bonds that a substance has.

21. To explain structures of Diamond and Graphite
22. To discriminate between atom and molecule.
23. To explain resonance hybrid

## APPENDIX B

### KİMYA DERSİ TUTUM ÖLÇEĞİ

AÇIKLAMA: Bu ölçek, Kimya dersine ilşkin tutum cümleleri ile her cümlenin karşısında Tamamen Katılıyorum, Katılıyorum, Kararsızım, Katılmıyorum ve Hiç 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 ile 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 C

## BİLİMSEL İŞLEM BECERİ TESTİ

**AÇIKLAMA:** 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 kabiliyelerini ölçebilen sorular bulunmaktadır. Her soruyu okuduktan sonra kendinizce uygun seçeneği yalnızca cevap kağıdına işaretleyiniz.

**1.** Bir basketbol antrenörü, oyuncuların güçsüz olmasından dolayı maçları kaybettklerini 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 antreman süresini.
**d.** Yukarıdakilerin hepsini.

**2.** Arabaların verimliliğini inceleyen bir araştırma yapılmaktadır. Sınanan hipotez, benzine katılan bir katkı maddesinin arabaların verimliliğini artıdığı 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 arabnın 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 değşkenleri araştımaktadırlar. 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 sebeblerini 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.

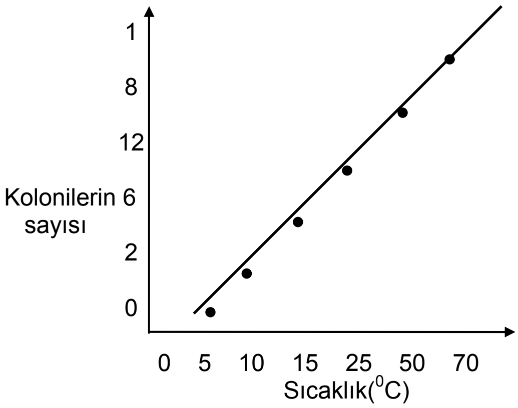
**d.** Isınma giderleri arttıkça ailenin daha ucuza ısınma yolları araması gerekir.

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

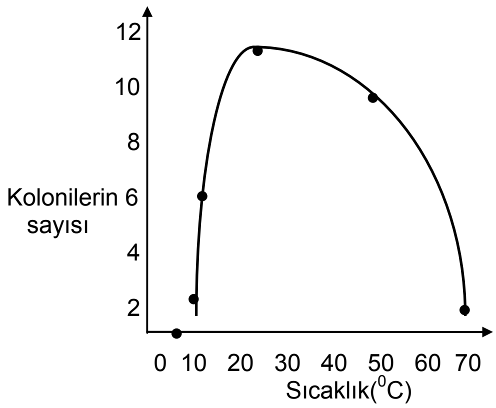
| Deney odasının sıcaklığı ($^{0}$C) | Bakteri kolonilerinin sayısı |
|---|---|
| 5 | 0 |
| 10 | 2 |
| 15 | 6 |
| 25 | 12 |
| 50 | 8 |
| 70 | 1 |

Aşağıdaki grafiklerden hangisi bu verileri doğru olarak göstermektedir?

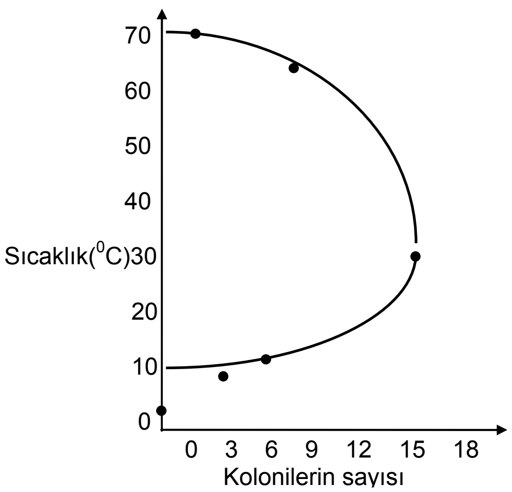
**a.**



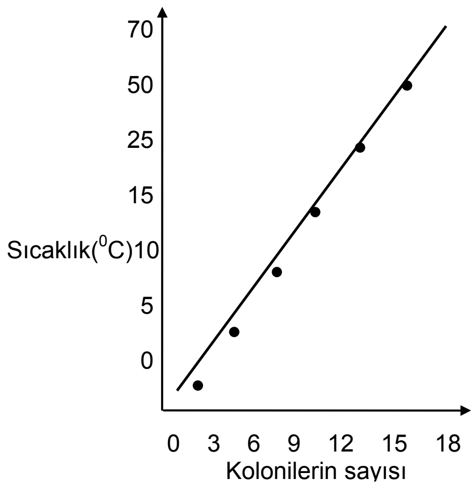

**b.**




**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?

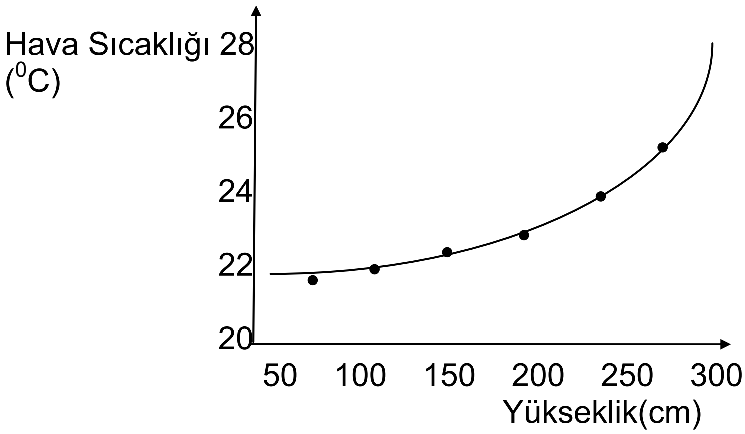
**a.** Daha genç sürücülerin daha hızlı araba kullanma olasılığı yüksektir.

**b.** Kaza yapan arabalar ne kadar büyükse, içindeki insanların yaralanma olasılığı o kadar azdır.
**c.** Yollarde 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. Br oyuncak arabaya geniş yüzeyli tekerlekler takılır, önce bir rampadan (eğiik 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 genişlkleri 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, k**a**r 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 sıcaklıklarla ilgli 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 ilşki yoktur.

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

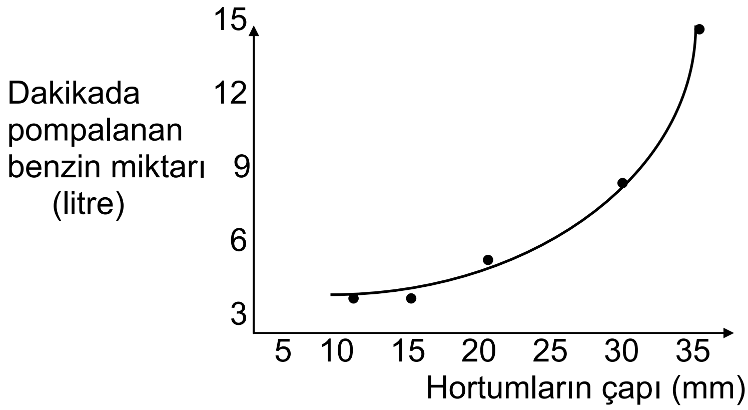
**a.** Topları aynı yükseklikten fakat değişik hızlarla yere vurur.

**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.

Bumlardan 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 maddelari 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.** Herbir 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.** Herbir 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.** Herbir kovanın güneş altında kalma süresi.
**16.** Can, yedi ayrı bahçedeki çimenleri biçmektedir. Çim biçme makinasıyla her hafta bir bahçedeki çimenleri biçer. Çimenlerin boyu bahçelere göre farklı olup bazılarında uzun bazılarında kısadır. Çimenlerin boyları ile ilgili hipotezler kurmaya nbaşlar. 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 nci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Murat, suyun sıcaklığının, su içinde çözünebilecek şeker miktarını etkileyip etkilemediğini araştırmak ister. Birbirinin aynı dört bardağın herbirine 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 herbir 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.** Kullanolan 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.** Araştımanın 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 alnlardaki 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 ya da spreyin miktarı ölçülür.

**b.** Toz ya da 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 liter soğuk su koyar ve 10 dakika süreyle ısıtır. Ebru, alevin meydana getirdiği ısı enerjisini nasıl öiçer?

**a.** 10 dakika sonra suyun sıcaklığında meydana gelen değişmeyi kayeder.

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

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

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

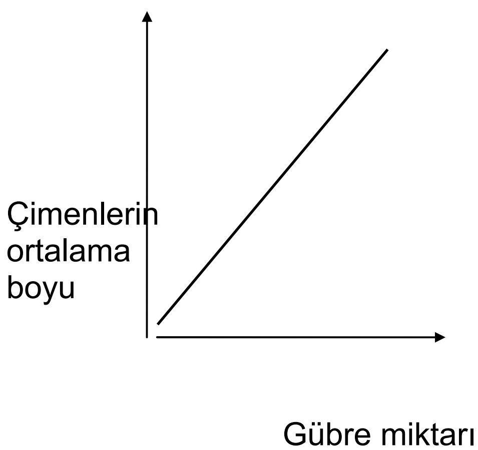
**d.** Herbiri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

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

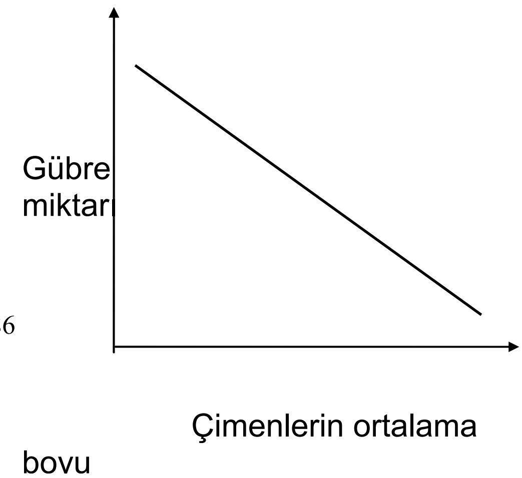
| Gübre miktarı (kg) | Çimenlerin ortalama boyu (cm) |
|---|---|
| 10 | 7 |
| 30 | 10 |
| 50 | 12 |
| 80 | 14 |
| 100 | 12 |

Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

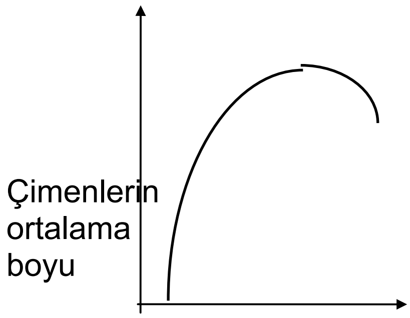
**a.**



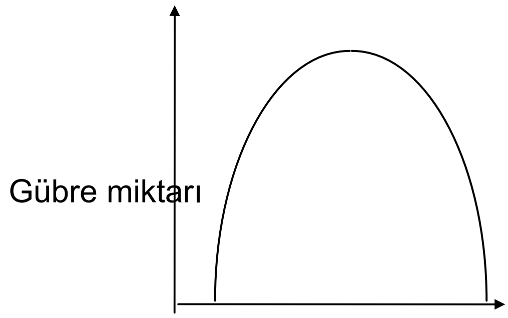

**b.**



**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.** Hergün fareleri tartar.

**d.** Hergün 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?

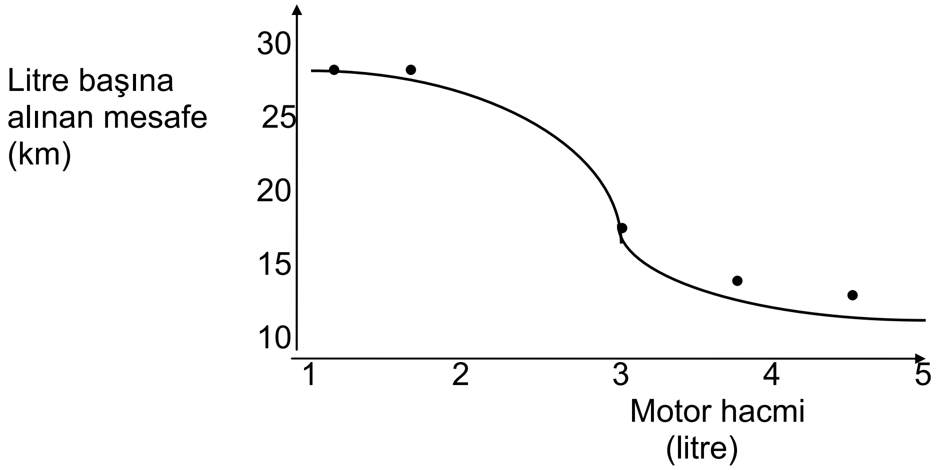
**a.** Daha fazla şekeri çözmek için daha fazla su gereklidir.

**b.** Su soğudukça, şekeri çözebilmek için daha fazl akarıştırmak gerekir.

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

**d.** Su ısındıkça şeker daha uzun sürede çözünür.

**28.** Bir araştıma grubu, değişik hacimli motorları olan arabalaıın randımanlarını ölçer. Elde edilen sonuçların garfiği 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 nci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Toprağa karıtırılan yaprakların domates üretimine etkisi araştırılmaktadır. Araştırmada dört büyük saksıya aynı miktarda ve tipte toprak konulmuştur. Fakat birinci saksıdaki torağa 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 eled 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 torak miktarı.

**d.** Çürümüş yapak karıştırılan saksı sayısı.

**31.** Araştırmadaki bağımlı değişken hangisidir?

**a.** Her saksıdan elde edilen domates miktarı

**b.** Saksılara karıştırılan yaprak miktarı.

**c.** Saksılardaki torak miktarı.

**d.** Çürümüş yapak karıştırılan saksı sayısı.

**32.** Araştırmadaki bağımsız değişken hangisidir?

**a.** Her saksıdan elde edilen domates miktarı

**b.** Saksılara karıştırılan yaprak miktarı.

**c.** Saksılardaki torak miktarı.

**d.** Çürümüş yapak karıştırılan saksı sayısı.

**33.** Bir öğrenci mınatısların 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 üle.

**b.** Demir tozalrını çeken mıknatısın ağırlığı ile.

**c.** Kullanılan mıknatısın şekli ile.

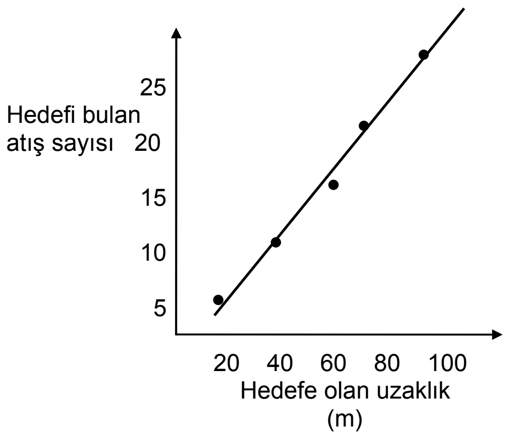
**d.** Çekilen demir tozlarının ağırlığı ile.

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

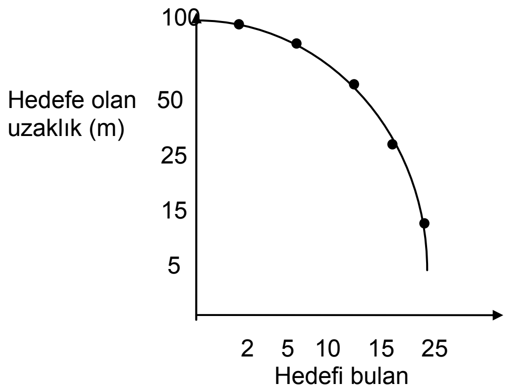
| Mesafe(m) | Hedefe vuran atış sayısı |
|---|---|
| 5 | 25 |
| 15 | 10 |
| 25 | 10 |
| 50 | 5 |
| 100 | 2 |

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?

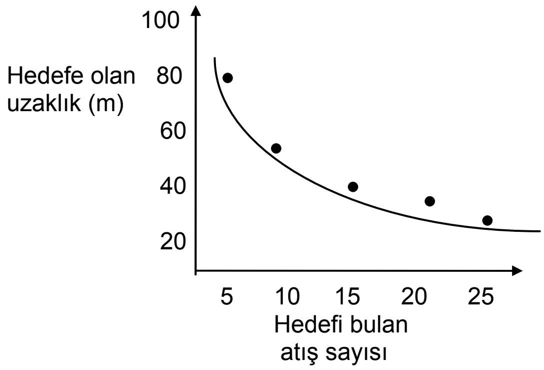
**a.**



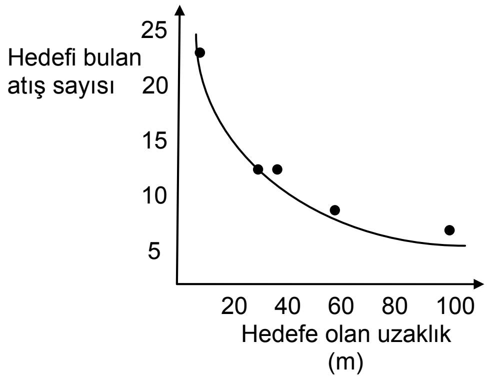

**b.**




**c.**




**d.**




**35.** Sibel, akvaryumdaki balıkların bazen çok haraketli 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 electrikli 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 makinesinin kullanma sıklığı.

**d.** a ve c.

## APPENDIX D

*Chemical Bonding Concept Test*

**This test consists of questions that examine your knowledge of chemical bonding. Each question has two parts: *a response section* in which you are asked to mark only one of two possible answers; *a reason section* in which you are asked to select the reason which explains the answer in the previous part of the question. On the answer sheet, please circle one answer from both the response and reason sections of each.**

**1) Water ($H_2O$) and hydrogen sulphide ($H_2S$) have similar chemical formulas and structures. At room temperature, water is a liquid and hydrogen sulphide is a gas. This difference in state is due to**

**(I)** forces between molecules
**(II)** forces within molecules

**Reason**

**A)** The differences in the forces attracting water molecules and those attracting hydrogen sulphide molecules is due to the differences in strength of the O-H and the S-H covalent bonds.

**B)** The bonds in hydrogen sulphide are easily broken whereas those in water are not.

**C)** The hydrogen sulphide molecules are closer to each other, leading to greater attraction between molecules.

**D)** The forces between water molecules are stronger than those between hydrogen sulphide molecules.

**2) The electron cloud distribution in the HF molecule can be best represented by**

**(I)** H :F **(II)** H **:** F **(III)** H**:** F

**Reason**

A) Nonbonding electrons influence the position of the bonding or shared electron pair.

**B)** As hydrogen and fluorine from a covalent bond the electron pair must be centrally located.

**C)** Fluorine has a stronger attraction for the shared electron pair.

**D)** Fluorine is the larger of the two atoms and hence exerts greater control over the shared electron pair.

**3) When NaCl dissolves in water, there are still ionic bonds between sodium and chlorine atoms in solution**

**(I)** True **(II)** False

**Reason**

A) NaCl exist as discrete pairs of $Na^+$ and $Cl^-$

B) Ionic bond is broken during the dissolving process.

C) Positive charges on sodium ions must be neutralized by gaining of electrons from chloride ions in the solution.

D) NaCl is still molecular in water.

**4) The boiling point of $N_2$ is very low ($-147^0C$), on the other hand, at high temperatures, it does not decompose due to**

**(I)** intermolecular bonds

**(II)** intramolecular bonds

**Reason**

**A)** Intermolecular forces between $N_2$ molecules are very strong.

**B)** Nitrogen atoms cannot achieve stable octet.

**C)** Intramolecular forces are weaker than intermolecular forces.

**D)** Triple bond is very strong compared to intermolecular (Van der Waals) forces.

**5) Graphite can conduct electricity because it has <u>delocalised</u> electrons.**

**(I)** True **(II)** False

**Reason**

**A)** Only three of the four valance electrons of a carbon atom are involved in bonding and the fourth electron is delocalised.

**B)** Electrons escape from the covalent bonds in graphite and are free to move within the molecule.

**C)** Graphite can conduct electricity because it has layers of carbon atoms, which can slip over each other.

**D)** Graphite can conduct electricity because in graphite, some carbon atoms are delocalised and they conduct electricity.

**6) Nitrogen combines with bromine to form a molecule. This molecule is likely to have a shape that is best described as (N, 5A; Br, 7A)**

(I) Trigonal planar (II) Trigonal pyramidal (III) Tetrahedral

Reason

A) Nitrogen forms three bonds, which equally repel each other to form a trigonal planar shape.

B) The tetrahedral arrangement of the bonding and nonbonding electron pairs around nitrogen results in the shape of the molecule.

C) The polarity of the nitrogen-bromine bond determines the shape of the molecule.

D) The difference in electronegativity values for bromine and nitrogen determine the shape of the molecule.

7) **The molecule $H_2O$ is likely to be**

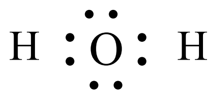
(I) V- shaped (II) Linear

**Reason**

A) Repulsion between the bonding and nonbonding electron pairs result in the shape.

B) Repulsion between the nonbonding electron pairs result in the shape.

C) The two Hydrogen-Oxygen bond are equally repelled to linear positions as $H_2O$ has an electron dot structure shown as



D) The high electronegativity of oxygen compared to hydrogen is the major factor influencing the shape of the molecule.

**8) The ''electron pair repulsion theory'' is used to determine the**

(I) polarity of a molecule

(II) shape of a molecule

Reason

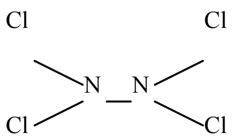
A) Nonbonding electrons determine the polarity of the molecule.

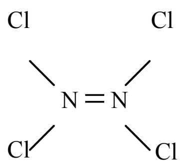
B) The theory states that the shape of the molecule is due to the arrangement of the bonding and nonbonding electron pairs around the central atom to minimize electron repulsion.

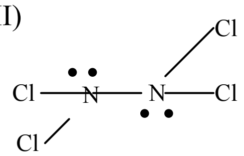
C) The theory states that the polarity of the molecule is dependent on the number of polar bonds present.

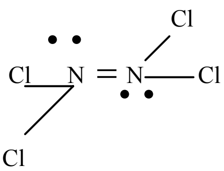
D) The theory states that the shape of the molecule is due to repulsion between the atoms in the molecule.

**9) Which of the following best represent the structure of $N_2Cl_4$?**

(I) 

(II) 

(III) 

(IV) 

**Reason**

A) The high electronegativity of nitrogen requires that a double or triple bond is always present.

B) The structure is due to repulsion between the five electron pairs (including bonding and nonbonding pairs) on the nitrogen atom

C) The structure is due to repulsion between the four electron pairs (including bonding and nonbonding pairs) on the nitrogen atom

D) The structure is due to repulsion between bonds in the molecule.

**10) In hydrogen chloride, HCl, the bond between hydrogen and chloride is a/an**

($_1$H, 1A; $_{17}$Cl, 7A)

(I) ionic bond

(II) covalent bond

(III) hydrogen bond

Reason

A) Hydrogen and Chlorine share one each electron in compound.

B) Hydrogen is bonded to a highly electronegative atom such as F, Cl and O

C) HCl is a strong acid, and it decomposes to its ions when it dissolves in water.

D) Hydrogen transfers one electron to chlorine to form a compound.

**11) The electronegativity of Lithium is 1,0 and the electronegativity of Hydrogen is 2,1. In the compound that is formed by Li and H elements the bond between atoms is**

($_3$Li, 1A, $_1$H, 1A)

(I) covalent bond

(II) ionic bond

(III) not observed

Reason

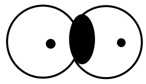
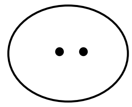
A) Li and H share one each electron in LiH compound.

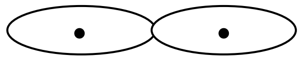
B) Hydrogen is positively charged in its compounds but in this compound it must be negatively charged.

C) Metals cannot combine with each other.

D) Li and H make an electron transfer to fill their outermost shells so $Li^+$, $H^-$ ions are formed.

**12) Which one of the following best represents the $H_2$ molecule? ($_1$H)**

(I)  (II) 

(III) 

Reason

A) Valance electrons of both H atoms move around the two nucleus.

B) Each shared electrons move around its belonging nuclei. When they are moving, sometimes they are located in the middle of the two nuclei and this location hold two H atoms together

C) When hydrogens are bonded together, their orbital do not overlap each other.

D) When $H_2$ molecule forms, half filled 1s orbital of two H atoms became filled.

$1s^1 + 1s^1 \rightarrow 1s^2$

**13) In ClF molecule, the bond between Chloride and Fluorine is**

(I) polar covalent bond

(II) nonpolar covalent bond

Reason

A) Chlorine and Fluorine are negatively charged in their compounds. There is not any ionic bond between them. That is, bond is 100 % covalent.

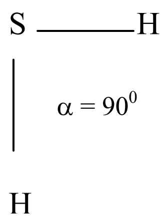
B) The electronegativity of two atoms is different

C) Both atoms join to Cl-F bond with one each electron.

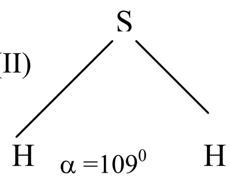
D) Cl has more electron than F.

**14) What is the bond angle of the $H_2S$ molecule ?**

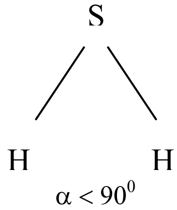
(I)



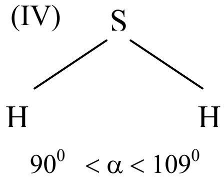

(II)




(III)




(IV)




**Reason**

A) Angle between $sp^3$ orbital is approximately $109^0$.

B) Angle between $sp^3$ orbital is approximately $109^0$ and nonbonding electrons on S affect the bond angle.

C) Angle between p orbital is $90^0$.

D) Angle between p orbital is $90^0$ and nonbonding electrons on S affect the bond angle.

**15) In solid NaCl, the nearest neighbor of one Na ion is six chloride ions. One sodium ion**

(I) is bonded to the specific Cl ion it donates its electron to.

(II) is bonded to any neighboring Cl ion.

(III) is bonded to all of its neighboring chloride ions.

Reason

A) In solid NaCl, one $Na^+$ ion is bonded to one neighboring chloride ion, and attracted to a further five $Cl^-$ions, but just by forces, not bonds.

B) Ionic bond is the attraction force between oppositely charged ions.

C) Ionic bond is the transfer of electrons to obtain filled valence shells.

D) Ionic bond between Na and Cl atoms is represented by Na-Cl.

**16) Hydrogen is liquid at low temperatures. Are there any attractive forces between $H_2$ molecules in the liquid hydrogen?**

(I) Yes (II) No

Reason

A) There is no electron transferring or sharing between Hydrogen molecules to form attractive force.

B) Particles in $H_2$ are uncharged.

C) There is a massive interaction between the particles.

D) There is a Van der Waals Forces between molecules.

**17) While solid $CF_4$ is melting,**

(I) the size of the $CF_4$ molecules changes

(II) the C-F bond weakens

(III) the bonds between $CF_4$ molecules weaken

**Reason**

A) The size of the $CF_4$ molecules in liquid state are smaller than the size of the $CF_4$ molecules in solid state, so the distance between $CF_4$ molecules in liquid state is larger.

B) The density of liquids is bigger than the density of solids. During the melting process, no mass change is observed so volume of $CF_4$ molecules should increase.

C) As the strength of the C-F bond increase, the melting point increase.

D) Heat given during the melting is used to weaken the bond between $CF_4$ molecules.

**18) At room temperature, sodium chloride, NaCl, exist as a molecule**

**(I)** True **(II)** False

**Reason**

**A)** The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule

B) After donating its valance electron

to the chlorine atom, the sodium ion forms a molecule with the chlorine ion

C) Sodium chloride exists as a lattice consisting of sodium ions and chloride ions

D) Sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms.

**19) What can be said about the polarities of $CCl_4$ and $CHCl_3$?**

(I) Both of them are polar

(II) Both of them are nonpolar

(III) $CHCl_3$ is polar and the other $CCl_4$ is nonpolar

**Reason**

A) A molecule is nonpolar, only if atoms of molecule have same electronegativities.

B) If molecule has tetrahedral shape, it is nonpolar.

C) If molecule contains polar bonds it is a polar molecule.

D) Polarity of molecule depends on the polarity of its bonds and shape of the molecule.

**20) Cl, Br and I elements are in 7A group. They found in nature as diatomic and show similar chemical properties. What is the reason that Chlorine ($Cl_2$) is gas, Bromine ($Br_2$) is liquid, and Iodine ($I_2$) is solid at room temperature?**

(I) Cl-Cl, Br-Br and I-I bond have not equal strength.

(II) $Cl_2$, $Br_2$, and $I_2$ molecules have different numbers of electrons.

(III) Electronegativity of Chloride, Bromine and Iodine are different from each other.

**Reason**

A) The attractive forces between the $I_2$ molecules, which have more electrons among them, are stronger than the others.

B) The most electronegative one is Cl. Electronegative atoms are more active so Cl move faster and it is in gas state.

C) Because Iodine has more protons, its nuclei pull electrons more strongly than the others.

D) I-I covalent bond is stronger than the others so $I_2$ is in solid state at room temperature.

**21) Breaking a chemical bond**

**(I) release energy**

**(II) require energy**

**Reason**

A) A chemical bond forms only if the molecule is more stable when it is unbonded.

B) Body produces energy by burning carbohydrates.

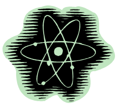
C) Some attractive forces hold atoms together in chemical bond.

D) Bond formation requires energy.

## APPENDIX E

### E.1 CONCEPTUAL CHANGE TEXT 1

It is well known that many people have wrong ideas about chemical bonding because it contains the concepts are seen abstract and the words from everyday language are used but different meanings. Different methods are used to change the wrong ideas of people and one of them is analogical model. Analogical models make abstract concepts to more familiar and concrete. Example for analogy;



"*The structure of atom is like a solar system*".

☹ Most students wrongly thought that there is a 1:1 correspondence between models and reality.

☺ However, it must be noticed that no single analogical model can fully illustrate an object or process, because if it did, it would be an example not a model.

☺ Accepted concept

☹ Misconception

### ☼ WHAT DO YOU THINK WHAT A CHEMICAL BOND MEANS?

☹ Most students thought that bonds are “things” that holds atoms together but they could not explain exactly what the “thing” is. They believed wrongly that chemical bonds are material connections simply.

☺ However, when we think scientifically, we see that there are forces that hold the atoms of elements together in a compound. These forces are called as “chemical bonds”. In other words, the “thing” between atoms you mentioned is the electrostatic forces that hold atoms together.

☼ *Analogy for chemical bond:*

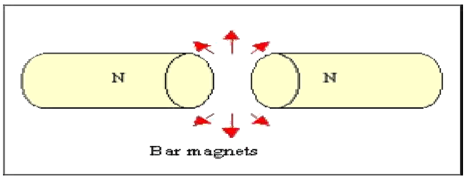



**Figure1**. Bar Magnets

You are familiar with magnets. The like poles of magnets repel each other, while the unlike poles attract each other. Atoms are electrically charged, thus attract and repel like the "poles" of a magnet. Attractions between particles of atoms leads to chemical bond and holds structure together.

**IN CHEMISTRY, BOND MEANS ELECTROSTATIC FORCES**

## WHY DOES CHEMICAL BOND OCCUR?

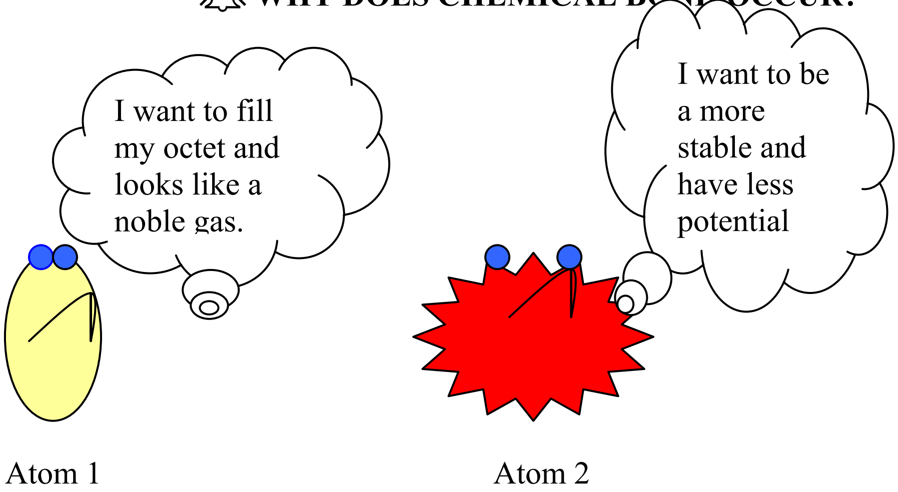



Figure 2**.** Why does chemical bond occur?

☹ Most of the students think like atom 1. They think that atoms are bonded together to fill their octet and reach a noble gas electronic structure (to obtain an octet).

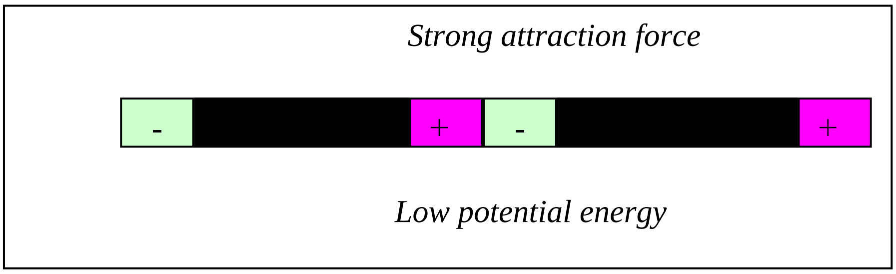
☺ However, this is not the mean reason. Yeah! Atoms try to looks like noble gases but not simply to fill their octet, they actually want to be more stable and have less potential energy.

**THE OCTET RULE IS NOT ONLY A GUIDE TO OBTAIN STABLE SYSTEM**

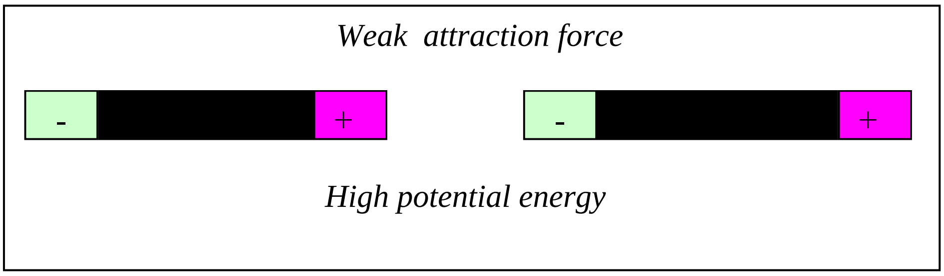
**FILLED SHELLS DO NOT PRODUCE BONDS.**

*Analogy for stability;*

Look at the following demonstrations.




Unlike poles of two magnets are put closer to each other and there is an attraction force between them, so energy must be given to pull them apart. What happens to given energy after parting?




☺ Energy never lost, it is taken by magnets and it cause increasing the potential energy of unlike poles. If separated magnets are leaving off, they naturally come closer and their potential energies decrease again by giving energy to surrounding. Also, they became more stable.

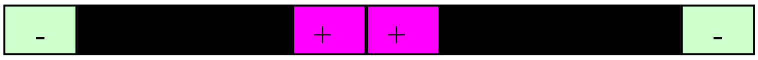
☺ Accepted concept

☹ Misconception

What will happen if like poles of two magnets are put closer to each other?

There is a strong repulsive force between them, so energy must be given to keep them closer to each other.

*Strong repulsive force*




*High potential energy*

If we leave off magnets, they will naturally separated by using given energy for separation, and they became more stable with low potential energy again.

*Weak repulsive force*


*Low potential energy*

**Like magnets, everything in nature want to have low potential energy and tend to became more stable. Atoms and molecules also have potential energy and this works similar to the potential energy of the magnets.**

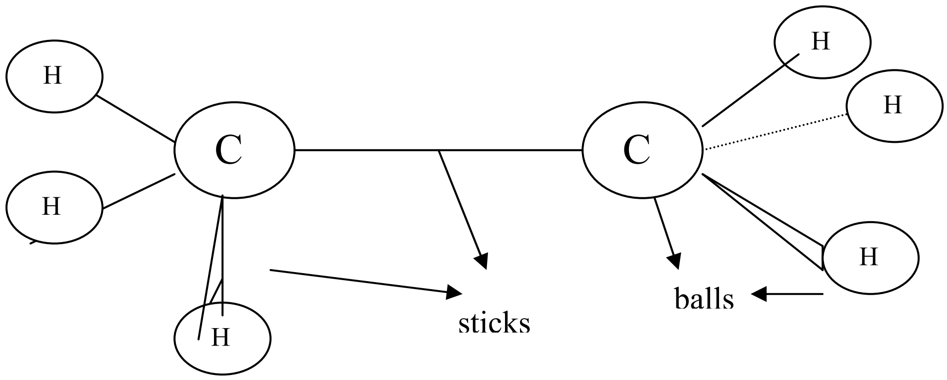
☺ Accepted concept

☹ Misconception

DOES BREAKING CHEMICAL BOND RELEASE ENERGY?

Some students think that breaking chemical bond release energy.

Let's look at the following ball-and- stick model of molecule.



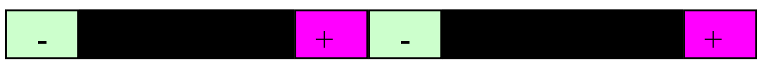

C : Carbon H : Hydrogen

Do any work has to be done to separate the atoms?

Remind them that the two atoms are connected, so must be attractive force holding them together (The attraction between the electrons of one atom and the nuclei of the other).

*Analogy for bond breaking*

In the following figure magnets are "pulled" together by attraction. Pulling them apart again obviously require work.




☺ This is similar to the attraction between electric charges. There are attractions between of two atoms that lead to chemical bonding. Therefore, breaking chemical bond require energy.

## 🕭 WHAT IS THE IONIC BOND?

☹ Most students say that ionic bonds are the transfer of electrons, rather than the attractions of the ions that result from the transfer of electrons. The reason for the transfer of electrons is to achieve a full shell.

These wrong ideas come from the misinterpretation of the definition of the chemical bond.

☺ Ionic bond is the attractive force between oppositely charged ions in an ionic compound.


***<u>Analogy for ionic bonding:</u>*** **Dog - Bone Bonds**

Let's use the natural attraction between dogs and bones as an analogy to the attraction between opposite charges.

**Ionic Bonds: One big greedy thief dog!** Ionic bonding can be best imagined as one big greedy dog steeling the other dog's bone. If the bone represents the electron that is up for grabs, then when the big dog gains an electron he becomes negatively charged and the little dog that lost the electron becomes positively charged. The two ions (that's where the name ionic comes from) are attracted very strongly to each other.

Let’s look at the above analogical model; Of course, this model does not match 100% with real bond formation. However, it makes ionic bonding concept more concrete and interesting.

What are the shared and unshared points of this analogical model with real model?

☺ Example for unshared point: In reality, after ionic bonds are formed, two bonded ions should be stable and happy with this electron transfer. However, in this model, dog that lost its bond does not happy and it does not want to lose its bond and it is an unshared point because it is not match with the scientific fact.

You can also find the other shared or unshared points for this analogy.

Homework Question 1-

…………………………………………………………………...

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*Your Analogy for ionic bonding*

**You can create an analogical model for ionic bonding and discuss the like and unlike points with real model and share it with your teacher and friends.**

Homework Question 2-

**…………………………………………………………………………………**

**…………………………………………………………………………………**

**…………………………………………………………………………………**

### 🕭 DOES BONDING OCCUR ONLY BETWEEN ATOMS THAT GIVE AND ACCEPT ELECTRONS?

☹ Some students wrongly think that bond are only formed between atoms that donate/accept electrons.

Let us think that how does bonding occur between Hydrogen and Fluorine atoms leading HF molecule? Is there an electron transferring occurring between atoms?

### 🕭 WHAT IS THE COVALENT BOND AND BOND POLARITY?

☹ Most of the students wrongly think that covalent bond holds atoms together because the bond is sharing electrons.

☺ In reality, the attractive force between shared electrons and nuclei of the atoms is a covalent bond.

☹ Some students think that number of covalent bonds formed by a nonmetals equal to the number of electrons in the valance shell.

☺ Accepted concept

☹ Misconception

Let’s look at the following example to check the reality of the above sentence.

*Example-1*

Calculate the numbers of electrons in the valance shell of Oxygen atom ($_8O$) and then calculate the number of bonds formed by oxygen atom in $O_2$.

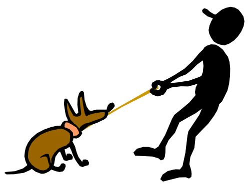
Is the number of valance electrons equal to number of bonds formed?

☼*Analogy for Nonpolar Covalent Bond;* **Dogs of equal strength**

Covalent bonds can be thought of as two or more dogs with equal attraction to the bones. Since the dogs (atoms) are identical, then the dogs share the pairs of available bones evenly. Since one dog does not have more of the bone than the other dog, the charge is evenly distributed between both dogs. The molecule is not "polar" meaning one side does not have more charge than the other.

☹ Generally students believe that equal sharing of the electron pair occurs in all covalent bonds so that all covalent bonds are nonpolar.

Let’s look at the following picture. In this picture, Man and dog share one string. But they are not equally sharing the string because man is stronger than the dog so he pulls more strongly than the dog.



This string sharing similar to sharing electrons pairs between the atoms that have different electronegativity in covalent bonding.

☺ Covalent bonds can be classified as nonpolar covalent bond and polar covalent bond. A nonpolar covalent bond forms when electrons are shared equally between atoms and a polar covalent bond forms when electrons are not shared equally. In polar bonds, the shared electrons tend to be pulled closer to more electronegative atom than to the other. Thus the element that attracts electrons more strongly acquires a partial negative charge (-δ), and the other acquires a partial positive charge (+δ). Since such a molecule possesses positive and negative poles, such bonds are called polar covalent bonds.

## BOND POLARITY

Most of the students think that;

☹ Ionic charges determine the polarity of the bond.

☹ The polarity of a bond is dependent on the number of valance electrons in each atom involved in the bond.

It is wrong. Let's look at $_{9}F$ and $_{35}Br$. They have same number of valance electrons but they form polar covalent bond.

☹ Nonbonding electron pairs influence the position of the shared electron pair and determine the polarity of the bond.

It is wrong because the polarity of the BOND is only affected by electronegativities of bonded atoms.

☹ Some students think that the largest atom exerts the greatest control over the shared electron pair.

☺ It is wrong because the shared electrons tend to be pulled closer to more electronegative atom, not to larger one.

*Analogy for Covalent Bond Types*

**Eating in a Restaurant**

A restaurant analogy for these situations could be as follows:
A nonpolar covalent bond is formed if you give your friend half of your cheeseburger in exchange for half of his chicken burger. A polar covalent bond would be like your friend taking all of your cheeseburger and in exchange giving you just a small bite of his chicken burger.

Homework Question 3-

*Create your analogy for one type of covalent bonding*

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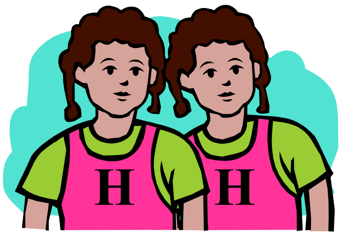
☹ The other common misconception held by some students is that bonding must be either ionic or covalent.

☺ Actually, no compound is 100% ionic. If the bond involves the same atoms (a homonuclear bond, A-A) then the bond must be 100% covalent because neither atom has the ability to attract the electron pair more strongly than the other. However, if the bond involves different atoms (a heteronuclear bond, A-B) the bond will have mixed covalent and ionic character. This means there will be a percent ionic character. Thus, except when the two atoms that are bonded are the same element (for example, two oxygen atoms), a bond is always partially covalent, partially ionic. The reason for this is that an electron is never completely transferred from one atom to another. The electron is shared rather than completely transferred. The sharing is a matter of degree-the concept of a polar bond.

## E.2 CONCEPTUAL CHANGE TEXT 2




Hydrogen atoms (H) do not exist freely in nature. They are found in nature as diatomic particles ($H_2$). They do this because gain a stable structure when they form diatomic particles.

### ***HOW TWO HYDROGEN ATOMS ARE HELD TOGETHER?***

There must be something to hold two positively charged nuclei together.

If the electrons lie between two nuclei, the attraction forces between the nuclei and electrons hold two hydrogen atoms together.

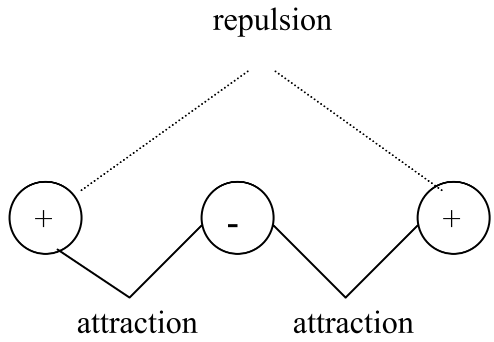



Figure 1- Interaction between H atoms in $H_2$

However, electrons lie outside of the both nuclei repel each other!!!!


***So, how can these two atoms overcome this repelling force to come together?***

☺ It is only possible, when they hit each other with enough energy to overcome this repulsive force between electrons. Thus, the half-filled 1s orbital of two hydrogen atoms overlap and produce a region of high electron charge density.

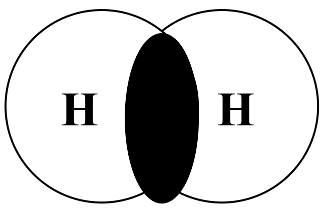



Figure 2-Covalent bonding in $H_2$

So, covalent bonding occurs when an electron spends most of its time in the region between nuclei and it is shared between them. As a consequence of the fact that two electrons between hydrogen atoms have been counted twice.

*Analogy for electrons between hydrogen atoms*:

Borrowing a book from a library can be used as an example. Although you get the book from library and you are treated as if it belong to you; yet at the same time, it is counted as being part of the library collection.

Is this analogy perfectly matched with reality? Of course it does not.

What are the shared and unshared points of this analogical model with real model?

Example for shared point:

* When you borrow a book from a library, library and you possess a book simultaneously. It is similar to electrons between hydrogen atoms, which are possessed simultaneously by two nuclei of hydrogen atoms and they have been counted twice.

Examples for unshared point:

* In $H_2$ particle, both H atoms simultaneously attract electrons and equally share them but when you borrow a book, only you use a book.

* In $H_2$ particle, electrons spend most of their time in the overlap area of the shells that is shared, but book is mostly with you.

* In $H_2$ particle, both H atoms share their one electron with the other one, but you do not have to share your own book with library for borrowing a book from library.

## 🔔 WHAT IS MOLECULE?

☹ Generally students have difficulty in differentiating between atoms and molecules. They would use “molecule” when they appeared to mean to say “atom”, vice-versa.

☹ Some students have misconception that the result of the attraction between the two oppositely charged ions formed is the neutralization or the canceling of charges, leading to the formation of a neutral molecule.

Another wrong believes among students is:

☹ Metals and nonmetals form molecules.

☹ Atoms of a metal and a nonmetal share electrons to form molecules.

☹ A metal is covalently bonded to a nonmetal to form a molecule.

☺ They are wrong because a molecule is a definite group of atoms that are covalently bonded together.

☺ All matter is made up of small particles. for example, the smallest part of a noble gas is an atom, the smallest part of ionic compounds is a positively and negatively charged ions and the smallest part of covalent compounds is a molecule.

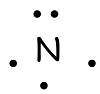
## Bonding Capacity of the molecule

☹ Some students think that nitrogen atoms can share five electron pairs in bonding.

☺ Let’s look at the nitrogen atom. The nitrogen atom is an element of group VA in the periodic table. It has five valence electrons.

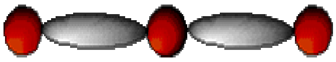
*Could nitrogen atom share five electrons in bonding?*

No, it could share three electrons in bonding. So, bonding capacity of nitrogen is equal to three.

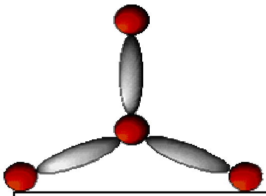


☺ Bonding capacity of an atom depends on the number of half-filled orbital (unpaired electrons).

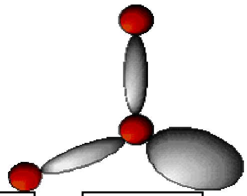
## ☼SHAPE OF THE MOLECULE



Linear

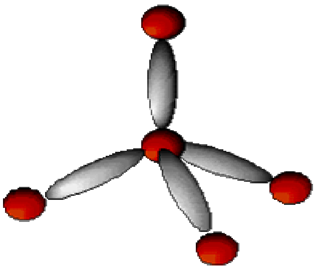


Trigonal Planar

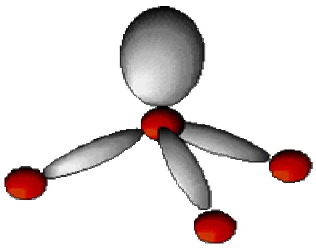


Bent

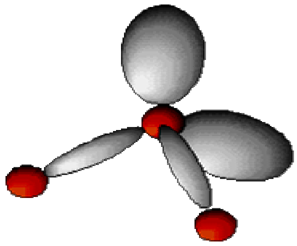
* The spheres represent the atoms in the molecule. The gray ovals represent bonding regions (a single bond, a double bond, or a triple bond - each represents one region). The large gray areas represent non-bonding pairs of electrons.



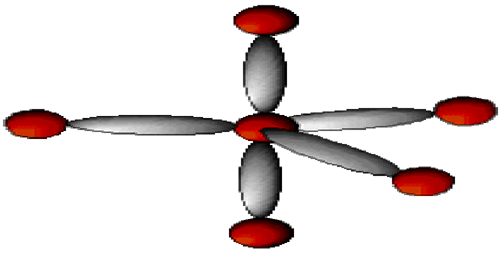
Tetrahedral



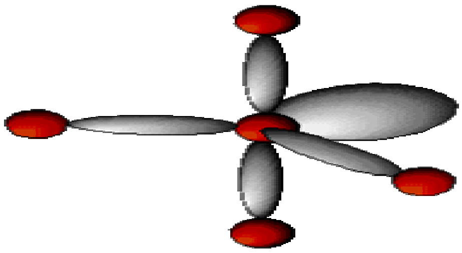
Trigonal pyramidal



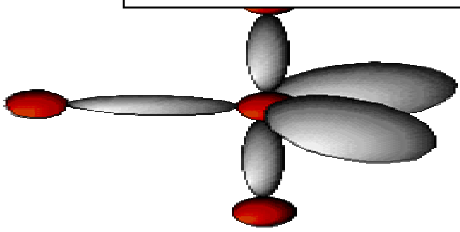
Bent



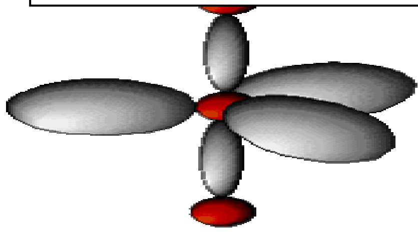
Trigonal bipyramidal



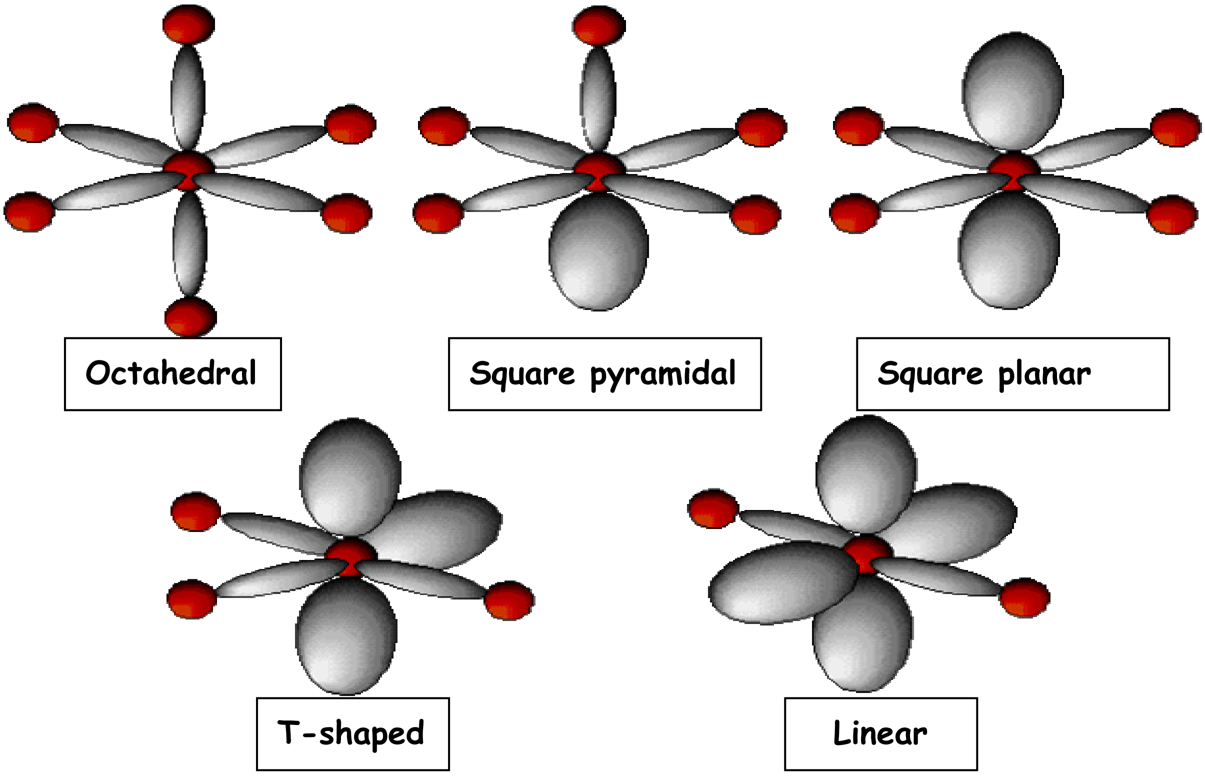
Distorted tetrahedron



T-shaped



Linear




Most of the students wrongly think that:

☹ Bond polarity determines the shape of a molecule.

☹ The shape of a molecule was due to equal repulsion between the bonds only.

☹ Only nonbonding electron pairs influenced the shape of the molecule.

☺ THEY ARE WRONG BECAUSE REPULSIONS BETWEEN ALL ELECTRON PAIRS (BONDING AND NONBONDING) RESULT IN THE SHAPE (ACCORDING TO VALANCE-SHELL ELECTRON-PAIR REPULSION THEORY)

## POLARITY OF A MOLECULE

☹ Most of the students wrongly believe that nonpolar molecules form ONLY when the atoms in the molecule have similar electronegativities.

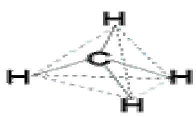
☺ It is wrong. If a molecule has more than two atoms, its shape can affect the polarity in a crucial way.

For example, in $CO_2$, since oxygen is more electronegative than carbon, each bond is highly polar. But the linear molecular shape makes the bond polarities cancel each other, so the $CO_2$ molecule is nonpolar.

$$O = C = O$$

☹ Most students say that a molecule is polar when it has polar bonds.

☺ Let's look at the $CH_4$ molecule. $CH_4$ molecule is a nonpolar molecule despite of having polar bonds. Each C-H bond is polar since carbon is more electronegative than hydrogen, however, each C-H bond in $CH_4$ is arranged symmetrically (all angles are $109.5^o$) so that the dipoles cancel out resulting in no net dipole for the molecule.




☹ Presence of nonbonding electrons determines the resultant polarity of a molecule.

☺ It is wrong because polarity of a molecule is determined by the polarity of bonds in the molecule and shape of the molecule.

☺ A non-polar molecule can be achieved by the molecule having:

I. only non-polar bonds

II. polar bonds arranged symmetrically so that the dipoles cancel out.

☺ A polar molecule is achieved in the molecule by the molecule being made up of polar bonds arranged unsymmetrical so that the dipoles do not cancel out

*Analogy for polarity of molecules*

Teflon-coated stirring bar magnets on an overhead projector can be used to illustrate an analogy between magnet behavior and polar molecule behavior. If the stirrers are spaced away from each other with a random orientation, then when a magnet passes near them on the overhead light stage, the magnetic stirrers will torque to align themselves parallel to the magnet's magnetic field. Polar covalent molecules behave similarly in an electric field.

Example: When $H_2$ is placed in an electric field, the orientation of $H_2$ molecules is random because $H_2$ is a nonpolar molecule. However, if HF molecules are placed in an electric field, HF molecules are oriented with their negative ends facing the positive plate and their positive ends facing the negative plate because HF is a polar molecule.

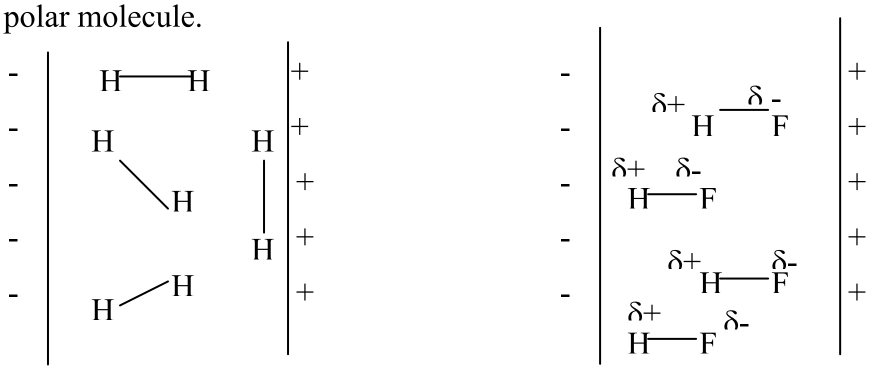



Figure 3- Orientation of nonpolar and polar molecules in an electric field

## COORDINATE COVALENT BOND

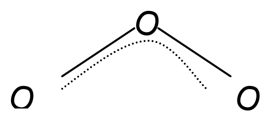
Coordinate covalent bonding is often described in a simple fashion by saying that it involves one atom donating or giving a pair of electrons to another, so that this bonding partner can have a full outer shell. When electrons are counted up in an electronic dot diagram, this coordinate covalent pair is counted with each of the atoms.

*Analogy for coordinate covalent bond*

A coordinate covalent bond forms if you notice a homeless person outside, bring them into the restaurant, and give them your whole dinner to eat.

## DELOCALIZED BONDING: RESONANCE

Delocalized Bonding: A type of bonding in which a bonding pair of electrons is spread over a number of atoms rather than localized between two. For example, the delocalized bonding in ozone might be symbolically described as follows:




According to resonance description, you describe the electron structure of a molecule having delocalized bonding by writing all possible electron dot formulas. These are called the resonance formulas of the molecule. The actual electron distribution of the molecule is a composite of these resonance formulas.

☹ Unfortunately, this notation can be misinterpreted and some students think that the ozone molecule flips back and forth between two forms.

☺ Actually, there is only one ozone molecule. The double-headed arrow means that you should form a mental picture of the molecule by fusing the various resonance formulas.

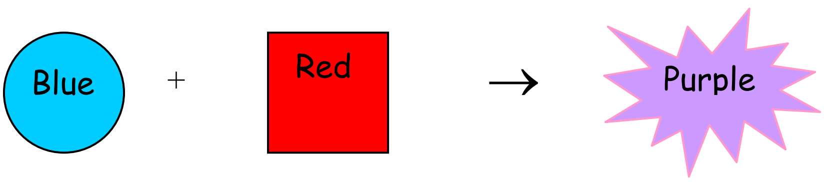
*Analogies for  Resonance Hybrid*

**1- Resonance Hybrid is like a Mule**

The actual electronic structure of or ion, which involves resonance, is often explained by saying the average of several contributing electronic structures, which are drawn so as to show the double bond in several different locations in the species. In order to remind students that the actual resonance hybrid structure doesn't alternate from one contributing structure to another from time to time, but rather has its own special structure all the time, it is convenient to use the analogy that a resonance hybrid is like a mule.

2- Blue + Red -> Purple

When blue and red colors are mixed (dye solutions, for example) the resulting color is neither blue nor red, but something intermediate. In other words, a "resonance hybrid" of the two individual colors. This might be illustrated as follows:

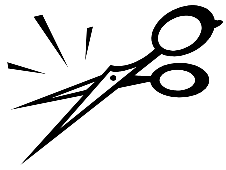


### 3- Political Parties

The picture of "extreme religions" or political parties as developed in the context of the chemical concept of resonance furnishes a good lead into a discussion of resonance. Remember, the "resonance" concept implies the existence of many facets, faces, and forms, but the real picture is none of those extremes entirely!

Also these analogies for resonance hybrid have shared and unshared points with reality!!!

## E.3 CONCEPTUAL CHANGE TEXT 3



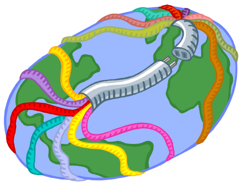
When you cut a piece of paper with scissors, what are you actually cutting? Is it is an atom or is it an electrical bond?

☺ When polymeric materials, such as paper, plastic, and skin, are cut, mostly what is being separated adjacent molecules, <u>held together by weak forces</u>. However, sometimes the actual polymer backbones are broken. When this happens, yes, it is an actual covalent bond that is being cut.

We said that mostly we separated adjacent molecules <u>held together by weak forces</u>. What are these weak forces between molecules that hold them together? ☺

☺ Let’s try to find answer. As you know, in ionic and covalent bond, *atoms* are held together within a molecule and they are known as intramolecular bond (within the molecule). However, we are looking for forces holding *molecules* together not holding atoms together so these forces between molecules cannot be an ionic or covalent bonds. Actually, we called this type of forces as intermolecular forces that hold molecules together.

## ☼ INTERMOLECULAR AND INTRAMOLECULAR FORCES



☹ Some students think that intermolecular bonds are the same as intramolecular bonds.

☺ Actually, there's quite a difference between these two types of bonds, despite their "sound-alike" nature.

For example:

☺ *Intramolecular* bonds refer to the forces of attraction that hold atoms together within a molecule. For example: covalent bonds, ionic bonds, and metallic bonds

☺ <u>Intermolecular</u> bonds refer to the forces of attraction that hold molecules together. For example: Hydrogen bonds, Van Der Waals bonds

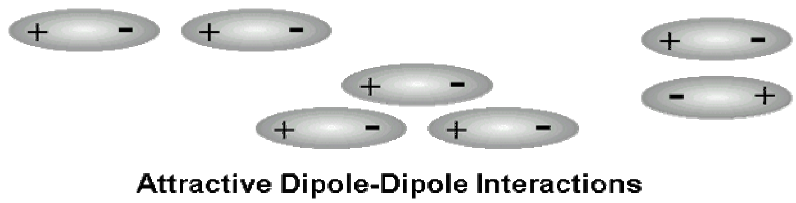
☺ *Intramolecular* bonds are *strong*, primary chemical bonds.

☺ <u>Intermolecular</u> bonds are quite weak forces that require relatively little energy to overcome.

## ☼ VAN DER WAALS BONDS

Van Der Waals forces result from the attraction of the positive nucleus of one atom on the electrons of an adjacent atom. Therefore Van Der Waals Forces are present in all matter. Van Der Waals Forces include dipole-dipole and London Forces.

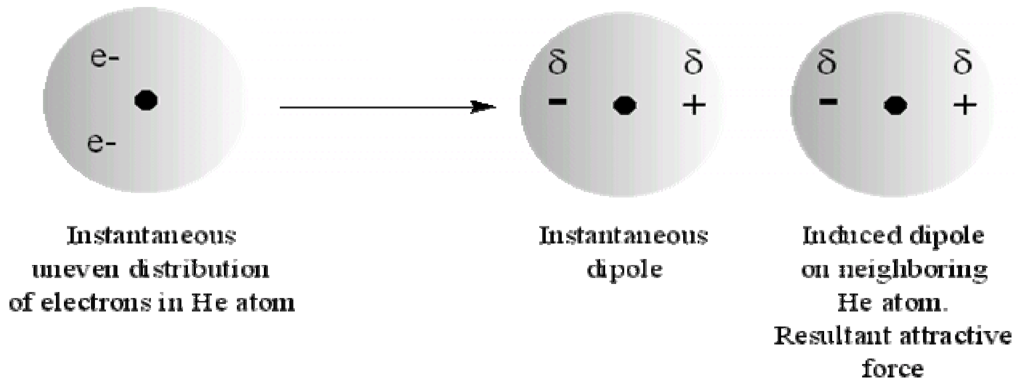
**Dipole-Dipole Forces**




Dipole-dipole force is an attractive intermolecular force resulting from the tendency of polar molecules to align themselves such that the positive end of one molecule is near the negative end of another.

**London (Dispersion) Forces**

London (Dispersion) Forces are the weak attractive forces between molecules resulting from the small, instantaneous dipoles that occur because of the varying positions of the electrons during their motion about nuclei.




***Due to electron repulsion, a temporary dipole on one atom can induce a similar dipole on a neighboring atom***

***Analogy for London dispersion forces:***

"The Wave", a popular ritual performed by fans attending sports events in large stadium, is like a London dispersion forces. There are similarities between people in the stands and electrons in atoms.

## HYDROGEN BONDING

☹ Most of the students confuse hydrogen bonding with a covalent bond between hydrogen and some other atom and they have trouble discriminating between molecules that could or could not hydrogen bond.

A hydrogen bond is a particularly strong dipole-dipole interaction between hydrogen attached to an electronegative atom and an adjacent atom, ion, or molecule containing an electronegative atom. The electronegative atom, which has at least one lone pair, is often nitrogen, oxygen, or fluorine. Hydrogen bond between molecules is shown as (……)

$$
\begin{array}{ccccccc}
\delta+ & & \delta- & & \delta+ & & \\
H & — & O & \cdots\cdots\cdots & H & — & O \\
 & & | & & & & | \\
 & & H & & & & H
\end{array}
$$

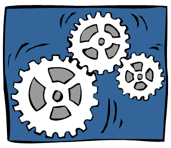
☹ Some students overgeneralize the atoms that are typically thought of as capable of hydrogen bonding, listing chlorine, sulfur, and carbon because of their proximity to nitrogen and oxygen (elements which students also stated were electronegative enough to be involved in hydrogen bonding)

This wrong idea comes from the rote memorization. Students state that electronegativity increase across the periodic table from left to the right, so elements to the right must be capable of hydrogen bonding. The strength or the size of the dipole, presence of unpaired electrons and relative sizes of the atoms involved are not addressed.

## WHAT IS THE MOLECULAR SOLIDS?

☹ Some students think that molecular solids consist of molecules with weak covalent bonding between the molecules.

*This idea is wrong. Molecular solid is a solid that consists of atoms or molecules held together by intermolecular forces. Many solids are of this type. Examples are solid neon, solid water, and solid carbon dioxide.*



## HOW THE METALLIC BOND ARISES?

Most students have many misconceptions in metallic bond concept. The common misconceptions found are as follows:

☹ Metals do not have any bonds since all atoms are the same.

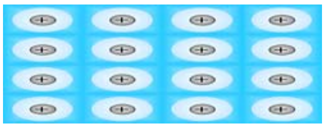
☹ There is some interactions in metals but there is not proper bonding. These students do not think the existence of bonds other than other than covalent or ionic.

☹ Metals have covalent and/or ionic bonding.

☹ Metallic bonding occurs only in alloys. These students have the idea that metallic bonding exists between two different metal atoms.

Metals have empty orbital in their outer shells. Furthermore their ionization energies are quite low. This proves that the valence electrons in metals are pulled very weakly to the nuclei of the atoms. With a little excitation, valance electrons gain a freedom of movement in the empty valence orbital of itself or in the empty valance orbital of the other neighboring atoms.

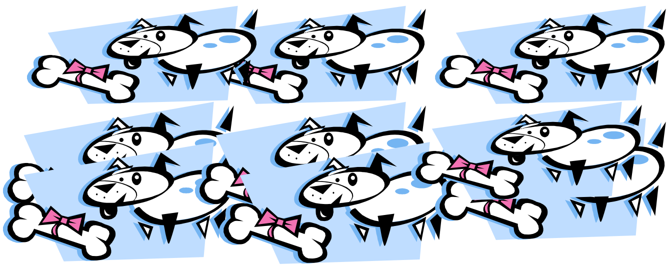
In other words, the valance electrons of atoms in a piece of metal neither shared nor donated to other atoms, but are free to move about in a piece of metal at random. These free electrons from a cloud of negative charge, a kind of Electron Sea, that fills the space between positive ions. The electrostatic attraction between the cloud of negative electrons and then positively charged nuclei of metal atoms holds the atoms together. This attraction force is called the metallic bond.



The nucleus and inner core of electrons are in a "sea" of delocalized, mobile valence electrons

***Analogy for Metallic Bonds:***

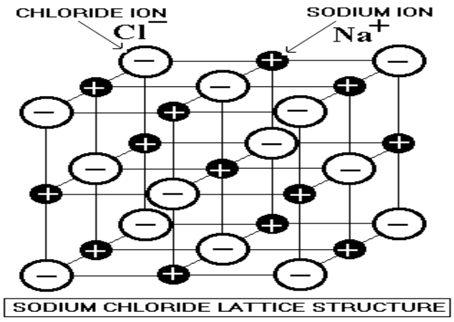
These bonds are best imagined as a room full of puppies that have plenty of bones to go around and are not possessive of any one particular bone. This allows the electrons to move through the substance with little restriction. The model is often described as the "kernels of atoms in a sea of electrons."



Of course, this analogy also has shared and unshared points with reality!

## ⛯ IONIC SOLIDS

Ionic solid is a solid that consists of cations and anions held together by the electrical attraction of opposite charges (ionic bonds). Examples are cesium chloride, and sodium chloride.




Sodium chloride consists of equal numbers of sodium ions, $Na^+$, and chloride ions, $Cl^-$, in a regular arrangement in space. For example, in sodium chloride, each $Na^+$ ions is surrounded by six $Cl^-$ ions, and each $Cl^-$ ions is surrounded by six $Na^+$ ions.

☹ The most common misconception among students was about the structure of ionic compounds, specifically the structure of NaCl.

They think that:

☹ NaCl exists as a molecule and these molecules are held together by covalent bonds.

☹ Na and Cl atoms are bonded covalently but the ionic bonds between these molecules produced the crystal lattice.

☺ *They are wrong because ionic structures do not contain molecules- there are no discrete ion-pairs in the lattice.*

Most of the students **wrongly** believe that:

☹ Ions interact with the counter ions around them, but for those not ionically bonded these interactions are just forces

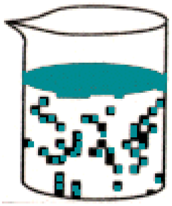
☹ An ionic bond only formed between atoms those donate/accept electrons (i.e., in sodium chloride a chloride ion is bonded to one sodium ion, and attracted to a further five sodium ions, but just by forces- not bonds)

☺ These ideas are wrong. Because a chemical bond is just the result of electrostatic forces- ionic bonds are nothing more than this. So, in sodium chloride a chloride ion is bonded to all of its neighboring sodium ions and the forces between a chloride ion and each of the neighboring sodium ions are equal).

☹ The other misconception held by some students is that atomic electronic configuration determines the number of ionic bonds formed (e.g., a sodium atom can only donate one electron, so it can only form an ionic bond to one chlorine atom)

☺ *In fact, the number of bonds formed depends on the coordination number, not the valency or ionic charge (e.g., the coordination is 6:6 in NaCl.*

## 🔔 HOW THE IONIC COMPOUNDS DISSOLVE IN WATER?

 ☹ Some students believe that $Na^{+}Cl^{-}$ bonds are not broken in dissolving; only inter-molecular bonds are broken.

☺ *In fact, $Na^{+}Cl^{-}$ bonds those are broken when the ionic compound is dissolved in water, resulting in $Na^{+}$ and $Cl^{-}$ ions*.

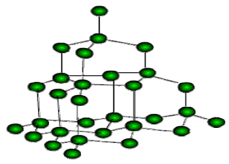
☹ Some students think that ionic compounds form neutral molecules, such as $Na^{+}Cl^{-}$ molecules, in water. *It is wrong.*

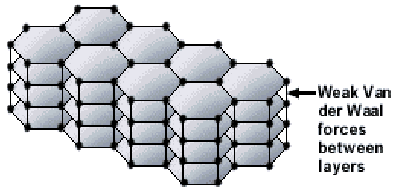
☺ *In water, ionic compounds dissociate into their ions, which are not neutral molecules because they possess a charge and the solution can act as an electrolyte.*

## COVALENT NETWORK SOLID

☹ Generally students think that strong intermolecular forces exist in a continuous covalent (network) solid.

However, covalent network solid is a solid that consists of atoms held together in large networks or chains by covalent bonds. Examples are diamond, and graphite.






**Structure of Diamond** **Structure of Graphite**

In diamond, one carbon atom is bonded to four other carbon atoms, but in graphite one carbon atom is bonded to three other carbon atoms.

☹ Thus some students may wrongly believe that there are " free" carbon atoms in graphite that move about and are responsible for conducting electricity.

☺ "Actually, o*nly three of the four valence electrons in an atom of carbon in graphite are involved in bonding, the fourth electron being delocalised within the layers of atoms, giving rise to the electrical conductivity of graphite."*

☹ Some students wrongly believed that the movement of the layers of atoms in graphite gives rise to its electrical conductivity.

This wrong idea might be because they think that mobile electrons and ions conduct electricity and therefore the layers of atoms could also conduct electricity because they could move.

## PHASE CHANGE

☹ Students held the misconception that intramolecular covalent bonds (instead of intermolecular bonds) are broken when a substance change phase.

☺ In fact, during a phase change for a substance like water, the change of state is due to the changes in the forces between the components
–e.g., $H_2O$(s) --> $H_2O$ (l) …the molecules are still unchanged during the phase chang

*"In a phase change there are no chemical bonds broken or formed, but the physical arrangement of the molecules changes"*

## APPENDIX F

PERCENTAGES OF STUDENTS' RESPONSES ON CHEMICAL BONDING CONCEPT TEST

| | | Post-test % | |
|---|---|---|---|
| **Item Number** | **Response** | **Experimental Group** | **Control Group** |
| 1 | 1* | 64.7 | 58.8 |
| | 2 | 23.5 | 29.4 |
| | A | 23.5 | 17.6 |
| | B | - | 17.6 |
| | C | - | 5.9 |
| | D* | 70.6 | 52.9 |
| 2 | 1* | 88.2 | 94.1 |
| | 2 | 5.9 | - |
| | 3 | - | - |
| | A | 11.8 | - |
| | B | 5.9 | 11.8 |
| | C* | 52.9 | 52.9 |
| | D | 23.5 | 29.4 |
| 3 | 1 | 47.1 | 64.7 |
| | 2* | 47.1 | 29.4 |
| | A | 35.3 | 11.8 |
| | B* | 29.4 | 35.3 |
| | C | 11.8 | 11.8 |
| | D | 17.6 | 35.3 |

| | | | |
|---|---|---|---|
| 4 | 1 | 52.9 | 52.9 |
| | 2* | 35.3 | 41.2 |
| | A | 35.3 | 23.5 |
| | B | - | 11.8 |
| | C | 47.1 | 29.4 |
| | D* | 5.9 | 29.4 |
| 5 | 1* | 76.5 | 41.2 |
| | 2 | 11.8 | 47.1 |
| | A* | 11.8 | 5.9 |
| | B | - | 41.2 |
| | C | 41.2 | 23.5 |
| | D | 35.3 | 23.5 |
| 6 | 1 | 41.2 | 35.3 |
| | 2* | 41.2 | 41.2 |
| | 3 | 5.9 | 5.9 |
| | A | 29.4 | 52.9 |
| | B* | 23.5 | 17.6 |
| | C | 29.4 | 17.6 |
| | D | 11.8 | - |
| 7 | 1* | 88.2 | 88.2 |
| | 2 | 5.9 | - |
| | A* | 47.1 | 58.8 |
| | B | 35.3 | 23.5 |
| | C | 5.9 | 5.9 |
| | D | 5.9 | - |
| 8 | 1 | 5.9 | 23.5 |
| | 2* | 82.4 | 70.6 |
| | A | 17.6 | 17.6 |
| | B* | 64.7 | 47.1 |
| | C | 5.9 | 5.9 |
| | D | 5.9 | 23.5 |

| | | | |
|---|---|---|---|
| 9 | 1 | 23.5 | 29.4 |
| | 2 | 29.4 | 41.2 |
| | 3* | 41.2 | 23.5 |
| | 4 | - | - |
| | A | 11.8 | 11.8 |
| | B | 17.6 | 29.4 |
| | C* | 58.8 | 41.2 |
| | D | 5.9 | 11.8 |
| 10 | 1 | 17.6 | 17.6 |
| | 2* | 76.5 | 70.6 |
| | 3 | - | 5.9 |
| | A* | 70.6 | 76.5 |
| | B | 17.6 | - |
| | C | - | 11.8 |
| | D | 5.9 | 5.9 |
| 11 | 1* | 41.2 | 52.9 |
| | 2 | 35.3 | 5.9 |
| | 3 | 17.6 | 35.3 |
| | A* | 47.1 | 52.9 |
| | B | 11.8 | 11.8 |
| | C | 5.9 | 23.5 |
| | D | 23.5 | 5.9 |
| 12 | 1* | 52.9 | 88.2 |
| | 2 | 5.9 | - |
| | 3 | 35.3 | 5.9 |
| | A | 29.4 | 5.9 |
| | B | 41.2 | 64.7 |
| | C | 11.8 | 5.9 |
| | D* | 11.8 | 17.6 |
| 13 | 1* | 64.7 | 64.7 |
| | 2 | 23.5 | 29.4 |

| | | | |
|---|---|---|---|
| | A | 11.8 | 35.3 |
| | B* | 47.1 | 47.1 |
| | C | 35.3 | - |
| | D | - | 11.8 |
| 14 | 1 | - | - |
| | 2 | 5.9 | 17.6 |
| | 3 | 23.5 | 5.9 |
| | 4* | 64.7 | 70.6 |
| | A | - | 17.6 |
| | B* | 76.5 | 47.1 |
| | C | - | 5.9 |
| | D | 17.6 | 17.6 |
| 15 | 1 | 47.1 | 29.4 |
| | 2 | 5.9 | 41.2 |
| | 3* | 41.2 | 17.6 |
| | A | 52.9 | 11.8 |
| | B* | 29.4 | 23.5 |
| | C | 5.9 | 11.8 |
| | D | 5.9 | 41.2 |
| 16 | 1* | 82.4 | 58.8 |
| | 2 | 11.8 | 35.3 |
| | A | 5.9 | 23.5 |
| | B | 11.8 | 11.8 |
| | C | 11.8 | 17.6 |
| | D* | 64.7 | 41.2 |
| 17 | 1 | 5.9 | 11.8 |
| | 2 | 5.9 | 23.5 |
| | 3* | 82.4 | 58.8 |
| | A | 11.8 | 11.8 |
| | B | 5.9 | 17.6 |
| | C | 23.5 | 11.8 |

| | | | |
|---|---|---|---|
| | D* | 52.9 | 52.9 |
| 18 | 1 | 17.6 | 52.9 |
| | 2* | 70.6 | 41.2 |
| | A | 17.6 | 17.6 |
| | B | 11.8 | 41.2 |
| | C* | 52.9 | 23.5 |
| | D | 11.8 | 11.8 |
| 19 | 1 | 11.8 | 41.2 |
| | 2 | - | 17.6 |
| | 3* | 76.5 | 35.3 |
| | A | 5.9 | 23.5 |
| | B | 17.6 | 17.6 |
| | C | 5.9 | 23.5 |
| | D* | 64.7 | 29.4 |
| 20 | 1 | 23.5 | 41.2 |
| | 2* | 29.4 | 29.4 |
| | 3 | 35.3 | 17.6 |
| | A* | 52.9 | 17.6 |
| | B | 17.6 | 5.9 |
| | C | 17.6 | 41.2 |
| | D | 5.9 | 23.5 |
| 21 | 1 | 29.4 | 23.5 |
| | 2* | 64.7 | 70.6 |
| | A | 11.8 | 5.9 |
| | B | 11.8 | 5.9 |
| | C* | 52.9 | 29.4 |
| | D | 17.6 | 52.9 |

## APPENDIX G

## INTERVIEW QUESTIONS

1. What does the term “chemical bond” mean to you?

2. How many chemical bonds do you know? Write the names of them.

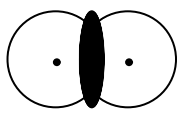
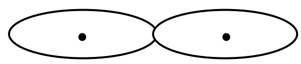
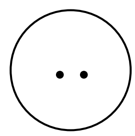
3. What does the term “ionic bond” mean to you?

4. Draw the structure and bonding for sodium chloride (NaCl). Explain why you drew it that way.

5. What happens when NaCl dissolve in water?

6. What does the term “covalent bonding ” mean to you?

7. Which of the following representations for $H_2$ molecule you prefer, which you dislike, and why for both options?

a-  b-  c- 

8. Could you please draw the shape of the nitrogen bromine molecule? (N, 5A; Br, 7A)

9. Why does the nitrogen bromine molecule adopt this geometry?

10. Could you please compare the arrangement of the water ($H_2O$) “molecules in water and stream” in a boiling kettle by drawing?

11. Could you please explain why graphite conducts electricity?

12. Could you please compare the intermolecular and intramolecular forces?

13. Could you please classify the following forces as intramolecular and intermolecular forces?

Van der Waals forces, metallic bond, ionic bond, hydrogen bond, covalent bond

14. The boiling point of $F_2$ is –188 $^oC$ and the boiling point of $Br_2$ is 58.8 $^oC$ . Therefore, Fluorine ($F_2$ ) is gas and Bromine ($Br_2$ ) is liquid at room temperature. Could you please explain the reason that this huge differences between the boiling points of $F_2$ and $Br_2$ molecules? (F, 7A; Br, 7A)

# APPENDIX H

## STUDENTS' HOMEWORK SAMPLES

**QUESTION 1:** Find the shared and unshared points for the "ionic bonding analogy" given in Conceptual Change Text-1 (dogs and bones analogy).

**Student A:** For unshared point: there is no interaction (as in the bond) between the doges. Instead, there is repulsion because they don't tend to stay together. Also, dogs do not have crystalline structure like ionic bonding atoms do.

For shared point: It is true that in an ionic bond, one is greedy and the other likes to give.

**Student B:**

Shared point: The big dog is stronger so it gets the bone: like electronegativity of atoms.

Unshared point: The small dog attracts to get the bone back but in ionic bonds they attract to each other because they become happy.

**QUESTION 2:** Create your analogical model for ionic bonding and discuss the like and unlike points with real model and share it with your teacher and friends.

**Student C:** Let's say that there are two children: Emre and Lale. It is Lale's birthday and Emre gives her a present (an electron). Lale becomes negatively charged and Eric becomes positively charged. They both became stable and happy. At first, Lale was excited because she was curious about the presents but now she knows Emre's present so she is stable. At first, Emre was excited because he was wandering if Lale does not like his present, but now he is stable, since he knows Lale is stable. Unlike points of my analogy is: Crystalline structure.

**Student D:** The relation between a shopkeeper and a consumer is not exactly but likely ionic bonding. The shopkeeper wants to sell the goods in the shop to earn some many and the consumer wants to buy the goods, as he/she needs them.
:) Like in ionic bonding one of them wants to sell the goods in the shop to get money and the other wants to buy them as a need.

:( Unlike in ionic bonding when the consumer is buying the goods he/she has to pay the money for them. And in order to earn money shopkeeper buys the goods, however, for ionic bonding one of the atom gives one of its electron and the other one takes it. No shopping taken place between them.

**QUESTION 3:** Create your analogical model for polar or nonpolar covalent bonding and discuss the shared and unshared points with real model and share it with your teacher and friends.

**Student E:** When you love somebody, you give your love to him/her. If you are living a nonpolar relation, he/she also loves you, but if it is polar, only you love him/her.

**Student F:** For nonpolar covalent bond: My friend and I joined a race and after a race we were both hungry and wanted to eat a hotdog, however, when we went to buy the hotdog we saw that there was only one left. As we were starving we bought the hotdog and divided it into two because both of us needed it. After we finished eating it we weren’t starving anymore and we were happy.

## APPENDIX I

## EXPERIMENTAL GROUP STUDENTS' OPINION ABOUT USE OF TEXTS AND ANALOGIES

**QUESTION 1:** 1. Do you prefer using analogies for explaining science facts? Explain.

**Student 1:** Yes. Because analogies were especially useful for understanding the difference between inter and intramolecular forces. Covalent and ionic bonding analogies were really useful.

**Student 2:**
Yes, definitely. Most students, I think, are having problems creating the images in their minds. Being able to compare the facts with analogies is a great opportunity.

**Student 3:** Using analogies for explaining facts are useful for everybody. Nobody gets bored while they are releasing the science facts.

**QUESTION 2:** Do you think that using conceptual texts useful for removing your misconceptions?

**Student 4:** Yeah, because conceptual texts really show me the things I misunderstand.

**Student 5:** Yes. The most useful part was that you gave the wrong examples as well as the true ones. It was of great help to remove my wrong beliefs.