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CHEMICAL EQUILIBRIUM MISCONCEPTIONS AMONG THE 12TH GRADE STUDENTS IN AL AIN PRIVATE SCHOOLS

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Education (Curriculum and Instruction)

Under the Supervision of Dr. Ali Khalfan Al-Naqbi

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Declaration of Original Work

I, Shahad Yahya Kayali, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*Chemical Equilibrium Misconceptions among the 12th Grade Students in Al Ain Private Schools*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Ali Khalfan Al-Naqbi, in the College of Education at the UAEU. This work has not been previously presented or published or formed the basis for the award of any academic degree, diploma, or similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and publication of this thesis.

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Abstract

This thesis aims at evaluating the understanding of the 12^{th}-Grade students in private schools towards four central concepts of the chemical equilibrium, these were i) the equilibrium constant; ii) approach to equilibrium; iii) heterogeneous equilibrium system; and iv) Le-Chatelier principle. The thesis also identified the misconceptions of chemical equilibrium across the student gender in the context of the United Arab Emirates. The collection of the required data allotted the Test to Identify Students' Alternative Conceptions (TISAC), which consists of two-tier multiple-choice questions. The required data drawn from the target sample of 206 12^{th}-Grade students included 122 females and 84 males enrolled in three private schools in Al-Ain city. We administrated the TISAC prior to conducting the descriptive statistics and *t*-test analyses. The generated findings revealed that the 12^{th}-Grade students showed different levels of chemical equilibrium understanding and insignificant statistical differences regarding the misconceptions among both student genders. The practical implications of the generated findings for the chemical curriculum developers and teachers are restructuring this part of the chemical course to erase the collective misconceptions from the four concepts of the chemical equilibrium. The thesis suggested some recommendations as a base for further investigations to overcome such misconceptions.

Keywords: Chemistry education, chemical equilibrium, misconceptions, 12^{th-}grade students, private schools, Al-Ain, the UAE.

Title and Abstract (in Arabic)

المفاهيم الخاطئة لدى طلبة الصف الثاني عشر حول التوازن الكيميائي في المدارس الخاصة في مدينة العين

الملخص

الغرض من هذه الدراسة هو تقييم فهم الطلبة حول التوازن الكيميائي في أربع مفاهيم رئيسية: ثابت الاتزان، نهج التوازن، أنظمة الاتزان الغير متجانسة، مبدأ لي-تشاتيلير. كما تم تحديد طبيعة المفاهيم الخاطئة بين الجنسين في سياق دولة الإمارات العربية المتحدة. لتحقيق غرض الدراسة، وجمع البيانات، تم استخدام اختبار تحديد المفاهيم البديلة للطالب والذي يتألف من مستويين لكل سؤال من أسئلة الاختيار. تم جمع البيانات من 206 طالبا من الصف الثاني عشر. تتألف عينة الاستبيان من 122 طالبة و84 طالبة في ثلاث مدارس خاصة في مدينة العين. أظهرت نتائج التحليل الكمي لبيانات الاستبيان أن لدى الطلبة المشاركين مستويات مختلفة من الفهم فيما يتعلق بمفهوم التوازن الكيميائي. وأشارت النتائج أيضا إلى عدد من المفاهيم الخاطئة التي يعقدها طلاب الصف الثاني عشر لكل من الجنسين. وأبرزت النتائج المفاهيم الخاطئة الشائعة في كل مفهوم من التوازن الكيميائي الذي يمكن أن يساعد مدرسي مقرر الكيمياء على التقليل من صعوبات التوازن الكيميائي. كما بينت الدراسة عدم وجود فروق ذات دلالة إحصائية بين الجنسين فيما يتعلق بالمفاهيم الخاطئة للتوازن الكيميائي. كما قدمت هذه الدراسة توصيات لواضعي السياسات ومطوري المناهج ومعلمي العلوم والكيمياء وإدارات المدارس تتعلق عن المفاهيم الخاطئة حول التوازن الكيميائي. وقد أدرجت بعض التوصيات لإجراء بحوث أبعد للتغلب على كل هذه المفاهيم الخاطئة.

مفاهيم البحث الرئيسية: التوازن الكيميائي، المفاهيم الخاطئة، الصف الثاني عشر، مدارس خاصة، العين، الإمارات العربية المتحدة.

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Dedication

To my dear mom, thanks for always being there for me; I love you immensely.

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List of Abbreviations

ADEK	Abu Dhabi Department of Education and Knowledge
TISAC	Test to Identifying Students’ Alternative Conceptions
UAE	United Arab Emirates

Chapter 1: Introduction

1.1 Background

Some researchers in science education consider chemistry as a problematic subject in science education (e.g., Hofstein & Lunetta, 2004; Hussein & Reid, 2009; Knaus et al., 2011). Sirhan (2007) attributed such difficulty to the *abstract* nature of chemistry, along with non-scientific conceptions that could be acquired by the learners. Consequently, the learners are not always able to better understand the new scientific concepts correctly other than those concepts existing in their minds. From an educational viewpoint, learning is a constructive process between the existing knowledge and new knowledge (e.g., Çam et al., 2015; Cook, 2017; Gabel, 1998; Sirhan, 2007). On the other hand, Novak (2002) pointed out the experience, prior knowledge, and other scientific concepts could conflict with the means of a scientific concept. Nevertheless, the students would be generating some concepts that might differ in meaning from those of the scientists. Such contrast in the concepts of both parties might be leading to the *misconception*, which is one of the hot research issues in chemistry education today.

Several studies about misconception in the chemistry field revealed that the concept of chemical equilibrium is one of the essential and fundamental concepts in chemical education (Akkus et al., 2003; Furio et al., 2000; Sirhan, 2007). Barke et al. (2009) acknowledged the chemical equilibrium as an enormously important prerequisite to gaining a better understanding of the fundamental concepts of the pure and applied chemistry, and chemical mechanisms in other disciplines, such as biology, geology, and medicine. For instance, the equilibrium concept in biology is used in the haemoglobin production at a high altitude, eyes adjusting to the light, and blood pH (Buthelezi et al., 2013). The research geologists are using the *dynamic equilibrium* landscape to explain the seismic uplift of an area balanced by the denudation from that area (Montgomery & Brandon, 2002). Furthermore, this concept is used in introductory courses to the nature of chemistry because it is involved in most of the general chemistry principles, such as reaction rate, acid-base, and oxidation-reduction (Yildirim et al., 2011) and Haber process (Buthelezi et al., 2013).

Chemical equilibrium is equally as important in students' conceptual understanding to avoid any misconceptions in the topic. Canpolat et al. (2006) indicated that a large body of research studies in chemical education had focused on students' understanding of chemical equilibrium concepts. These studies showed that students have several misconceptions regarding chemical equilibrium. These misconceptions are on different concepts related to chemical equilibrium, such as equilibrium constant, heterogeneous equilibrium systems, effect of catalyst, and Le Chatelier's principle according to some researchers in the field (e.g., Banerjee, 1991; Hackling & Garnett, 1985; Huddle & Pillay, 1996; Quilez-Pardo & Solaz-Portales, 1995; Wheeler & Kass, 1978; Voska & Heikkinen, 2000).

Karpudewan et al. (2015) mentioned that numerous studies intensively investigated the chemical equilibrium at high schools and university undergraduate levels. The researchers also summed up that since the 1960s, the same misconceptions are still existing challenges, and nothing has been done to improve such situation in several countries. Many students at all levels struggle to learn chemistry, and many do not succeed (Bius, 2016; Naah, 2012; Wood, 2013). For instance, in Spain, the undergraduate students in the first year at university acquired "*misapplication*" and "*misunderstanding*" related to the chemical equilibrium concepts in Spain (Quilez-Pardo & Solaz-Portoles, 1995). In Malaysia, the 12^{th-}grade students also showed a limited understanding of chemical equilibrium concepts (Karpudewan et al., 2015).

However, chemistry instructors from different colleges and universities identified the common difficulties students face in chemical equilibrium in the U.S. (Piquette & Heikkinen, 2005). Science teachers also showed that students did not have a satisfactory understanding of the chemical equilibrium concepts in Turkey (Özmen, 2008). Uzuntiryaki et al. (2003) revealed that students of high school hold concepts different to the scientific concepts of the chemical equilibrium. Azizoglu et al. (2006) found that undergraduate pre-science teachers also had incorrect scientific concepts in chemical equilibrium.

There are many sources of students' misconceptions in chemistry, including chemical equilibrium. According to Özmen (2008), researchers have been using the term misconception for most alternative concepts that result from life experience, scientific language, and instruction. The researcher added that all misconceptions arrived through the process of instruction either from the teachers and the textbooks or the specific complexity of other science subjects. Gomez-Zwiep (2008) also reported that students could get misconceptions from school, their teachers, and their textbooks.

Misischia (2010) observed that self-developed concepts made by learners do not often match with the scientific concepts. Also, when students get involved in a complicated subject matter, a new type of problem is born, and this is school-made misconceptions (Naah, 2012). The most common misconceptions also occurred from the scientific language source. Özmen stated that many students' ideas concerning chemical equilibrium had become a popular research area because of the abstract nature of many chemical concepts and the difficulty of the language of chemistry (2008).

According to Camacho and Good (1989), there is a wide range of misconceptions about the chemical equilibrium because usually this topic is taught as a separate topic instead of being taught as an integrating synthesis. Many studies which have been carried out in chemistry detected that students have difficulties in learning chemical equilibrium due to its abstract nature (Gussarsky & Gorodesky 1990; Huddle & Pillay 1996; Maia & Justi, 2009; Quilez 2004; Yildirim et al., 2013). Those studies have found that students have learning difficulties and misconceptions due to the abstract nature of the chemical equilibrium because students are unable to imagine the equilibrium event.

As a result of both national and international literature review about chemical equilibrium, Piquette and Heikkinen (2005) and Yildirim et al. (2013) revealed that students had misconceptions related to chemical equilibrium in these concepts: dynamic nature of equilibrium, Kc, heterogeneous equilibriums, gas equilibriums, and Le-Chatelier principle, as well.

1.2 Statement of the Problem

This thesis aimed at gaining some insights into the understanding of chemical equilibrium among both student genders of the 12^{th}-grade in the context of the private schools in Al Ain city, the UAE. The relevant literature paved a hub for investigating the problem of *misconceptions* in chemical education; notably, the chemical reaction and equilibrium phenomenon, which barely researched in the UAE context.

At the international level, many studies indicated that both students and teachers are always facing many difficulties in understanding the chemical equilibrium. Such difficulty created a broad form of alternative concepts for more than three decades (e.g., Atasoy et al., 2009; Banerjee, 1991; Canpolat et al., 2006; Karpudewan et al., 2015; Piquette, 2001). At a national level, ADEK is entrusted to superintending and inspection a programme called *Irtiqa'a* “progression” to maximising students' performance and achievements by decreasing the *alternative* concepts in science subjects to pace with international efforts and trends towards reducing students' misconceptions about chemical equilibrium. For Example, Canpolat et al. (2006) found that thinking skills have a positive effect on students’ conceptual success of chemical equilibrium.

There is also a gap in the Emirati-related education research work concerning the impact of gender on understanding the chemical equilibrium concepts. Another motive to focus on this research problem was that the UAE Vision 2021 places much concern on building robust science education programmes to boost and push its ranking in the Trends in International Mathematics and Science Study (TIMSS).

1.3 Purpose of the Study

The purpose of this study is therefore to investigate misconceptions of chemical equilibrium among 12th-grade students in selected private schools working under Al Ain Educational Office. The thesis specifically focuses on three areas:

i) Assessment of students understanding of chemical equilibrium.

ii) Exploring the influence of gender on students understanding of chemical equilibrium.

iii) Identifying the nature of misconceptions concerning the fundamental four concepts, viz: an equilibrium constant, approach to equilibrium, heterogeneous equilibrium systems, and Le-Chatelier principle.

1.4 Research Questions

This thesis made an effort to answer the following proposed research questions about students' misconceptions of chemical equilibrium:

i) *What are the levels of the 12th-grade students' understanding about the chemical equilibrium*?

ii) *What are the natures of misconceptions bought by students about the main four concepts of the chemical equilibrium*?

iii) *What would be the impact of student gender on an understanding of chemical equilibrium*?

1.5 Significance of the Study

The theoretical and practical value of this study is based upon the understanding of chemistry in general, and better understanding chemical equilibrium in particular. Also, this study is significant as it concentrates on identifying science students' misconceptions of chemical equilibrium.

The previous studies about the misconceptions in chemical equilibrium were conducted outside the UAE. Therefore, this study is a baseline for misconceptions about the chemical equilibrium of students in the UAE. The findings of this study, therefore, will be a valuable source of information to curriculum developers and chemistry teachers for future planning and teach in this region since there is no evidence found of any similar studies conducted in the UAE context according to the researcher's knowledge.

1.6 Definition of Terms

- ***Chemical equilibrium***: Buthelezi et al. (2013) defined this term as "*when the forward and reverse reactions balance each other because they are taking place at equal rates* as Rate $_{\text{forward reaction}}$ = Rate $_{\text{reverse reaction}}$". In this study, chemical equilibrium is operationally defined in a similar way as when the reverse reactions reach the point where the rate of the forward reaction equals the rate of the backward reaction.
- ***The equilibrium constant***: According to Buthelezi et al. (2013), the equilibrium constant, K_{eq}, is the numerical value expressed as the ratio of the molar concentrations of the products to the molar concentrations of the reactants with each concentration raised to a power equal to its coefficient in the balanced chemical equation. Equilibrium constant has constant value at a fixed temperature as for the following reaction:

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

In this study, the chemical equilibrium is defined similarly as Brown et al. (2013) defined it: K_{eq} is the numerical value of the reaction quotient if the reaction is in equilibrium at a specified temperature.

- ***Le-Chatelier principle:*** Brown et al. (2013) stated: "*if a system at equilibrium is disturbed by a change in temperature, pressure, or the concentration of one of the components, the system will shift its equilibrium position to counteract the effect of the disturbance*" (p.639). However, Buthelezi et al. (2013) mentioned this principle in the statement: "If a stress is applied to a system at equilibrium, the system shifts in the direction that relieves the stress". They added that stress is any change in a system at equilibrium that upsets the equilibrium. In this thesis, Le-Chatelier principle operationally describes how an equilibrium system shifts in response to either stress or a disturbance.
- ***Misconception***: Alwan (2011) defined "misconceptions" as preconceived notions, non-scientific beliefs, naive theories, mixed conceptions, or conceptual misunderstandings. In this study, the term misconception is used to denote students understanding of scientific concepts that are in disagreement with the scientifically acceptable definitions.

1.7 Scope and Limitations

1] The area covered in this study. Al-Ain city was relatively small area compared with other Emirates. Also, this study collected the required data from three private schools in Al-Ain City to affect the generalisation of the results.

2] The participants were the students enrolled in advance high school track, i.e. 12^{th}-grade. This track prepares the students to join science, technology, engineering, and medicine (STEM) programmes at higher education levels.

3] The instrument of this study, which was translated to Arabic to fit with the students' knowledge.

4] The thesis focused only on four concepts as main attributes to investigating understanding of chemical equilibrium. These concepts are a part of the 12^{th}-grade curriculum of the UAE Ministry of Education for the public schools.

5] The students participated in this research study had no prior knowledge of the chemical equilibrium as this concept is taught in 12^{th}-grade for the first time. This may have contributed to their performance in the test of the chemical equilibrium.

Chapter 2: Literature Review

2.1 Chapter Overview

This chapter presents and discusses previous research findings related to the presence and prevalence of student misconceptions generally. Also it presents the results of studies, which were related to the chemical equilibrium from both international and national perspectives. The chapter starts with establishing a theoretical framework to conceptualise misconceptions and then moves on to reviewing pertinent literature on misconceptions, including a description of what they are, how they are formed, and how they impact learning. A review of the literature on misconceptions in science, chemistry and chemical equilibrium, and studies related to the UAE context before summarising the main findings were provided.

2.2 Theoretical Framework

This current research is built on the foundation of constructivism and conceptual change theories, for their relatedness and implications of the current study. Therefore, the framework begins with a brief review of the constructivism theory and misconceptions, followed by the conceptual change theory.

Over the last decades, the constructivism theory of learning had a significant impact on learning, teaching and educational research field (Colliver, 2002; Gordon, 2009; Lunenberg, 1998; Williams, 2017). According to Colliver (2002), Sevier-Laws (2008), and Zhang (2015) the constructivism theory is a constructive process by which learners' prior knowledge and experience interact with the surrounding world to construct new knowledge.

In other words, Bianchini and Colburn (2000) posited that learners are not "empty vessels" to transfer the knowledge from the mind of a teacher to the learner's minds. Instead, individual learners had also their own experience and knowledge that sometimes had significantly influenced the incorrect formation of knowledge (Colliver, 2002; Naylor & Keogh, 1999; Naah, 2012). Miller (2008) also agreed that the constructivism theory included the idea that learners created knowledge even if it is not matching with the scientifically acceptable knowledge. Reed (2012) explained this by noting that the students had the freedom to structure the new knowledge with their prior knowledge to have a convinced understanding.

Aoude and Fadi (2015) found that prior knowledge does not always help students to understand the reality or be satisfied with the scientific concepts; therefore, sometimes it forms a state of disequilibrium. As Wilson (2012) explained, the cognitive disequilibrium is one of the psychological states that face learners when they have objections, difficulties, challenges and disagreements between the new knowledge and their prior knowledge. Many researchers referred that the basis of the state of disequilibrium is the learners' misunderstanding or misconceptions which is explained clearly in studies of Keeley (2012) and Miller (2008).

Arneson (2005) stated that the misconceptions formed when the learners interpret two concepts in their cognitive structure and when they formed unaccepted concepts with the scientific concepts. To learn scientifically, students need to change their misconceptions and reform their understanding to reach the scientific concepts with sufficient support from their teachers. Within the field of education, Reed

(2012) pointed out that teachers had an important role to construct the student's concepts through the process of learning. Pilitsis and Duncan (2012) also noted that teachers had a responsibility to assess the students’ misconceptions to increase the chances of conceptual change through the learning process. Duit et al. (2008) and Friedman (2012) stated that the conceptual change is the gradual process that is concerned with the restructuring of knowledge.

Furthermore, Miller (2008) found that the conceptual change theory serves as the foundation by which it could view misconceptions as conceptions that need to be changed to match scientifically accepted theories. Wilson (2012) claimed that the conceptual change would validly be done if the learner was actively engaged in the process of learning and meaningfully constructed his understanding. Thus, recognition of what misconceptions are can significantly help teachers and educators to find the best way to facilitate the learning process (Nelson, 2014).

Within this framework, many studies revealed that the conceptual change theory could be viewed as processes that guide the learner to change his perception of concepts within the scientifically accepted conceptual understanding (Broers, 2008; Kambouri, 2012; Sackes, 2010). What we expect, based on this notion of conceptual change, is to change the conception of learners to the commonly accepted conceptions by the scientist. Therefore, students change the conceptual framework that helps them to solve problems, explain phenomena, and function in their world (Wood, 2012). The educators emphasised that the conceptual change be an essential key to the science learning process because it had influenced on their students by having a deep understanding according to DiBenedetto (2015). Based upon a review of the literature from several perspectives to examine how researchers worked on setting up the conceptual change theory that contributed to reshaping the thoughts, beliefs, attitudes, and values of students through a series of shifts.

Michael et al. (2016) analysed the literature reviews into learning and teaching of chemical equilibrium through conceptual change. The study indicated that the chemical equilibrium is one of the difficult concepts in chemistry. The researchers found that the learning and teaching process has to consist of different instructional techniques because each technique modified a particular misconception and highlighted an important point. The study also found that the conceptual change in chemical equilibrium had the power to enhance students' understanding of concepts.

2.3 The Understanding of the Students' Misconceptions

The learning process is an ongoing process all through a person's lifetime. Therefore, if the learner had any wrong knowledge throughout the learning process, it would impact future learning concepts (Shook, 2003). That is why it is important to know that students have concepts similar to the scientific concepts in science learning process. Sometimes, the students' concepts are not in accord with accepted ideas by the scientific community (Baze, 2017). For example, the word "work" differs in the science context from its everyday meaning (Gray, 2006).

That is also supported by Küçüközer and Kocakülah (2007) who found that the students had common words in their everyday language that had a meaning different from their meaning in science. In the same study, the researchers investigated students' misconception in physics regarding the electric circuits in Turkey; they used a conceptual understanding test and semi-structured interviews. The participants were 76 students from three different classes in ninth-grade. At the end of the study, the researchers claimed that the Turkish language was the main reason for students' misconceptions. In another study of 105 pre-service teachers and 91 7^{th} grade students by Korur (2015), it was found that both teachers and students had misconceptions in astronomical concepts. Instead, teachers themselves had misconceptions in very basic knowledge regarding astronomy.

There is a wide range of concepts to explain the phenomenon of disequilibrium between learners' knowledge and scientific knowledge. The term "misconception" had multiple meanings across the past years such as 'alternative framework' (Taber, 1998), 'alternative understanding' (Mashnad, 2008), 'naïve theory' (Ramnarain & Van Niekerk, 2012) and 'misunderstanding' (DiBenedetto, 2015). The previous researchers were all used to mean the same thing based on the philosophy applied to the misconception. Therefore, most researchers used them synonymously in their studies. Over the past two decades, many researchers started using the term "misconception" that referred to the knowledge which was not in agreement with accepted knowledge by scientists such as Canpolat et al. (2006), Case and Fraser (1999), Garnett et al. (1995), and Karpudewan et al. (2015). Also, Al-Rubayea (1996) mentioned that the term "misconception" was the most used term to describe this phenomenon.

Other researchers reported that students might have ideas different from what intended by the instruction in many areas as physics, chemistry, biology, and mathematics such as Azizoglu et al. (2006), who found that "misconception is used to indicate the identified scientifically incorrect idea of the students which occur when new information cannot be connected appropriately to the students' cognitive structure that already holds inappropriate knowledge" (p.947). This situation causes weak understanding or misunderstanding of the concept for the students. Therefore, it is essential to identify the sources of misconceptions.

Many studies in science education indicated that there were many sources of science students' misconceptions. These sources were included teachers, parents, media, life experience, and textbooks. Many researchers concluded that those sources had a role and power to transfer the wrong knowledge, such as Canpolat et al. (2006), Hanuscin (2007), Mashnad (2008), Misischia (2010), and Sampath Kumar (2016). Additionally, Shook (2003) noted that any explanation related to the visual learning used by the teachers or in the textbooks such as maps, diagrams, graphs, images, and equations could be another source of the students' misconceptions because the students' ability differs proportionally. Cohen and Kagan (1979) and Hanuscin (2007) reported another cause; when two or more learned concepts got mixed up, new misconception would emerge. Furthermore, the learners are usually not aware of their misconceptions, or they have incorrect knowledge; therefore, it seemed hard to fix their old knowledge.

2.4 Studies Related to Students' Misconceptions in General

Students, of all ages, in different countries, may ascribe to misconceptions. The presence of misconceptions means a serious problem in learning science because they could negatively affect students' understanding of many subjects related to science, such as biology, physics, and chemistry. For instance, control variables are used in the experimental work of the science subjects. Therefore, any misconceptions related to control variable could affect the learners' understanding of the science subjects. Tairab (2016) assessed 128 students' understanding of the control of variable. He used an assessment framework developed and implemented by the American Association for the Advancement of Science (AAAS). The results were analysed across grade level and indicated that students had numerous misconceptions related to control of variables that are considered as a key of the experimental setup. Also, the results suggested that students had to improve their scientific knowledge to fix their scientific misconceptions.

Malkoc (2017) also focused on students' understanding of another scientific concept, which was salt dissolution process to decline its misconceptions by using the animation. The participants of this study were 135 students from high school. The instrument was pre-post-test to measure the difference between the control and experiment groups. The results indicated that the animation developed a better understanding of the common misconceptions on solubility concepts.

In another study across the United States, high school students were found to have misconceptions regarding bonding in a study by Luxford and Bretz (2014). In this study, twenty-eight high school chemistry students were first interviewed, followed by the administration of the Bonding Representations Inventory (BRI) across 1072 students to test the prevalence of the misconception. It was found that there were four themes of misconceptions including periodic trends, electrostatic interactions, the octet rule, and surface features. A large number of participants and the diversity across different states give the researcher a comprehensive view of the misconceptions found in the states.

Misconceptions of scientific concepts were not restricted to school- age children only. Many other studies were conducted at the university level and showed similar trends. Nehm and Reilly (2007) reported such trends in their study that aimed to address students' misconceptions of the natural selection for biology students at a college in the United States. The sample investigated in this study were two classes of majors' and second-semester biology students at an urban college in the Northeastern United States. The classes were characterised by traditional teaching strategy and active learning strategy. The results showed that the active learning class had significantly decreased the misconceptions in natural selection concepts of evolutionary understanding but there were contrast effects in the traditional class.

Rosenblatt (2012) examined 1000 engineering students from first-year to fifth-year to address their difficulties with physics. The students enrolled in a science course that is required by all engineering programs at Ohio State University. The instruments were interviews, free responses, and multiple-choice tests to identify areas of difficulty about physics topics. The findings showed that students had misconceptions about the directional relationship between net force, velocity and acceleration in one dimension.

Similarly, Nelson (2014) found that the learners' misconceptions of emergent semiconductor phenomena limited their understanding in several topics related to science learning in different subjects such as chemical bonding, electricity and magnetism, energy, and the nature of science. In Nelson's study, the sample was 33 males and eight females who were engineering undergraduates. Almost all of the participants had finished their second physics course linked to electricity and magnetism. The researcher developed the instrument that was used by Brem and colleagues (2012) who studied the same topic. The participants had to answer the questions after viewing a simulation. The findings revealed that students ascribed to numerous misconceptions about semiconductors. The findings were interpreted about prior knowledge of semiconductors gained from previous courses. However, to make the findings valid for generalizability, the sample size could be expanded.

Misischia's (2010) study explored ten males and nine females who were undergraduate students from a movement science department at a Midwestern public university. All participants completed one college course in biology, and that course had covered the topics of diffusion and osmosis. The instrument was a short answer misconception test, and it included 28 items that identified students' misconceptions about the processes of diffusion and osmosis. The test included three parts that explained nine short- answer definitions, seven true and false questions with explanation, and 12 short-answer questions linked to three scenarios provided. The results showed that students had misconceptions about the processes of diffusion and osmosis, particularly in the third part of the test, which indicated that most students answered by guessing.

In another aspect, studies related to misconceptions have also dealt with demographic variables such as gender. Researchers such as Gray's (2006) had confirmed gender-based differences in misconception. He examined 266 eighth grade middle school students (males and females) to determine the gender differences in concept development in science. The instruments were a multiple-choice questionnaire that had the typical misconceptions with the correct answers and random interviews to determine the background knowledge for the two groups and how the participants could explain their answers. The results showed that there was a significant difference in types and some science misconceptions between girls and boys. The results also showed that the boys tried to explain their answers even when they were wrong while girls were unconfident about their answers even when they were correct.

The previous studies indicated that students might ascribe to a misunderstanding of scientific concepts at all educational levels. Whenever new knowledge was available, the learner started to find the new linkage between the new and previous knowledge. Also, the misconceptions were rooted and cemented as a viable knowledge to be used to interpret the world for these students.

2.5 Studies Related to Students' Misconceptions in Chemical Equilibrium

Chemical equilibrium is one of the chemical topics that has shown misconceptions among students. Karpudewan et al. (2015) found that the chemical equilibrium is one of the difficult topics in chemistry. They indicated that students, even when correctly provide answers to chemical equilibrium related questions, could not able to explain their answer to prove their full understanding.

Also, the researchers reported that the chemical equilibrium is one of the essential topics that appear to be a prerequisite to many concepts. Their findings showed that the students' conceptions of chemical equilibrium were affected by many factors such as students' prior knowledge that resulted in students' misconceptions related to basic chemical equilibrium ideas which can be summarized in: (1) the rate of the reaction could increase or decrease until the equilibrium happens, (2) there was a relationship between the concentration of reactants and products, and (3) any change made to a system at equilibrium, the reaction would go any direction to reduce this change.

These findings are in line with other findings that suggested students had difficulties to understand the chemical equilibrium and its concepts which were on dynamic nature of equilibrium, equilibrium constant, heterogeneous equilibrium, gases equilibrium and Le- Chatelier principle (Alkan & Benlikaya, 2004; Piquette & Heikkinen, 2005; Yildirim et al., 2011).

Hackling and Garnett (1985) identified the misconceptions of chemical equilibrium using the interview as an instrument. This research revealed that the typical misconceptions were about the approach to equilibrium, changing equilibrium conditions, the effect of a catalyst and the effect on the equilibrium constant. The findings of the previous study indicated that students had a poor understanding of chemical equilibrium concepts and their prior knowledge influenced their understanding.

Uzuntiryaki et al. (2003) investigated students' misconceptions regarding chemical equilibrium. The researchers administrated a written test to examine all students' misconceptions by adopting Hackling and Garnett's test (Uzuntiryaki et al., 2003). The test consisted of three parts which multiple choices were, true-false and open-ended questions. The test included four conditions related to chemical equilibrium concepts which were (1) approaching equilibrium (2) dynamic nature of equilibrium (3) changing equilibrium conditions and (4) effect of the catalyst. The test was translated into Turkish by researchers. Furthermore, the researcher conducted interviews with 20 students to reveal the reasons for their responses. This study found that students had 29 misconceptions in four categories of chemical equilibrium. According to the researchers, the results of this study supported the results of many other studies, such as Camacho and Good’s (1989), Hackling and Garnett’s (1985), and Voska and Heikkinen’s (2000).

The findings indicated the importance of rectifying all students’ misconceptions by improving the teaching methodology. This study is considered as a gate for further studies such as effective strategies to enhance the learning process of scientific concepts and how it is important to be aware, as teachers and educators, of students’ misconceptions. The recommendations are based on how teachers can improve their teaching methods related to the chemical equilibrium concepts by demonstrating chemical equilibrium concepts using models and analogies, covering all teachers’ misconceptions, and simplifying chemical equilibrium categories.

Özmen (2008) investigated students’ misconceptions of chemical equilibrium concept in Turkey. The researcher developed and used a test to identify students’ alternative conceptions (TISAC) as an instrument. It was two-tier multiple choices to find the reason behind the choice of the students. The first tier is related to content knowledge with three choices, while the second tier is related to reasons for the content response. The areas that the instrument evaluated were: an approach to equilibrium, application of Le-Chatelier’s principle, the constancy of the equilibrium, and effect of a catalyst. The results showed that the participants had 17 misconceptions related to the concept of chemical equilibrium. The range of the correct answers in the first tier was between 48% and 78%, while the range of correct answers in both tiers was decreased to 22.2% and 48.8%. In this study, the researcher analysed a group of misconceptions under different concepts related to chemical equilibrium situations. The findings indicated that a majority of participants had an inadequate understanding of chemical equilibrium concepts.

Voska and Heikkinen (2000) investigated the misconceptions related to the problem-solving situations in Le-Chatelier principle, the constancy of equilibrium constant, and effect of a catalyst. The sample consisted of 95 general chemistry students at the University of Northern Colorado. The research used a diagnostic test and interviews to collect the data. The findings showed that 53% of students had correct answers and only 33% of them had right reasons. Also, the researcher found that the percentage of students who had misconceptions related to Le Chatelier principle was 57%, while 40% was related to the constancy of equilibrium constant, and 19% to effect of a catalyst.

Piquette (2001) focused on strategies that could address all familiar students' misconceptions related to chemical equilibrium. Faculty survey regarding chemical equilibrium and interviews were the instruments used in this study. The survey consisted of four parts. Each part was designed to answer one of the research questions. All parts were case studies of students' misconceptions. The participants were fifty-two general chemistry instructor volunteers. The interviews were completed for only whose responses needed any clarification. The researcher found that faculty participants could identify approximately 60% of students' misconceptions regarding chemical equilibrium. Also, 15% of participants used strategies to cover all their students' misconceptions. Some of the participants (8%) stated that different ways of presentations could make the topic more understandable for students. The interviews failed to add new findings to what was already found in survey findings. Also, the researcher found out additional findings to answering the research questions. For example, the factors of students' misconceptions consist of chemistry curriculum and the role of web-based research as a tool because the researcher sent the surveys by email to all faculty participants.

Some researchers were used different strategies to minimise the misconceptions related to the chemical equilibrium such as Canpolat et al. (2006). The researchers explored 85 undergraduate students about chemical equilibrium concepts from two classes of an Introduction to Chemistry. One class formed the control group that was taught through traditional instruction, whereas the other class formed the experimental group that was taught through the conceptual change approach (conceptual change texts accompanied by a model and demonstration). In this study, the instrument was Chemical Equilibrium Concepts Achievement Test (CECAT). In the light of the findings obtained from the result of the study, students in the experimental group had performed significantly better than students in the control group based on the test results.

In another study, Maia and Justi (2009) investigated the learning of chemical equilibrium for the first-year medium – level class of 26 high school students (fourteen to fifteen years old) using of modelling – based teaching approach. This study, however, limited its scope to the qualitative understanding of the chemical equilibrium because it focused on how the equilibrium process happens to help students visualise the process. The findings showed that all groups had complete and coherent models for the qualitative understanding of chemical equilibrium. The researchers concluded that the diagram “Model of Modelling” could be an influential tool for modelling – based teaching in the development of students learning the process. In additions, this study indicated that students sometimes used their previous ideas on their models to allow students to develop understanding consistent with the scientific principles or concepts, but that may also give them an opportunity to correct any pre-existing concepts.

Yildirim et al. (2011) investigated how the worksheets affect the students' achievement of chemical equilibrium by using quasi-experimental design. The instruments in this study were Chemical Equilibrium Conceptual Test (CE-CT), interviews and observations. The participants had pre-test for their prior knowledge, and they were in 2 groups, experimental and control. The pre-test showed that all participants had the same background and prior knowledge about chemical equilibrium. The worksheets had different parts, and each part had its directions and aims. In the last part of the worksheets, the purpose was to reinforce students' knowledge with their new learning. Additionally, teacher-centred was the way of teaching for the control group. The interviews and observations were analysed to obtain data that was used with other findings from CE-CT. The findings revealed that experimental group's scores were better than control group's scores; this suggests that worksheets supported the way of teaching related to chemical equilibrium more than the traditional way of teaching did. Also, the worksheets added special favour to students' achievement and that what was stated during the interviews. The worksheets were considered as an activity for the student to analyse record and observe which helped them to change their prior knowledge of continual learning.

2.6 Studies Related to Gender Differences in Science Education

Many studies focused on gender differences showed that there is a gender gap in academic achievements in certain areas related to science generally and chemistry particularly. The main factor of gender differences was a culture that played a key role according to McCleary (2008). Also, parents and environment could promote gender stereotypes. According to Al Harahsheh (2011), gender stereotypes and roles in early childhood could affect in negative way children's improvements, such as their academic, economic, and health levels in their future life.

Gray (2006) emphasised that students' academic improvements be related to the gender factor. The researcher added that males could improve their science concepts better than females. The purpose of the previous study was focused on the number and type of the misconceptions related to astronomy. The sample was conducted for 8th-grade students from both genders. The researcher used a multiple-choice questionnaire consisting of several misconceptions with the correct choice for 226 students conducted by the teachers in addition to interviews with selected students (10 boys and 10 girls). The findings highlighted that males were trying to explain their answers by “correct” or “incorrect” with a high level of confidence using their science concepts or experience. Female students who gave correct answers had a low level of confidence to explain (Gray, 2006). Based on the findings of the previous study, there were more males who had correct answers with correct concepts than females who had correct answers by guessing.

Also, Greenfield (1996) and Stafslien (2001) found that the male students showed better prior knowledge experience than female students. Another study reported similar findings that male students had better performance than female students in science and mathematical achievement (Al Zarooni, 2014). Al Zarooni’s study revealed significant findings of gender differences and the misconceptions; male students improved their understanding using the guided inquiry based on student- centred learning more than female students did.

On the other hand, Greenfield (1996) investigated the students' academic achievement within the context of gender by using Stanford Achievement Test (SAT) in 4 levels primary, intermediate, advanced and task. The sample was 228 students (120 female students and 108 male students) from four different ethnic groups in the University of Hawaii in the USA. The results showed that female students had better results in first two levels than male students on the science achievement test, while male students had better results in advanced and task levels. This finding contrasted with the finding that reported by Praat (1999) that there were no significant gender differences related to students achievement and participation in New Zealand from 1986 to 1997. This study summarised the results of the ministry of education's researchers about students' achievement and participation regarding gender differences across ten years.

2.7 Studies Related to UAE Context

Studies about chemical equilibrium related to the UAE context are rare. There were almost no studies about students' misconceptions related to the chemical equilibrium in the context of United Arab Emirates (UAE). This scarcity of previous research findings highlights the critical role of the findings of this study and how it may add value to the knowledge base of UAE context.

However, there were few studies that dealt with misconceptions and chemistry. For example, Haidar and Al Naqabi (2008) aimed to determine the levels of understanding of 11^{th}-grade students about stoichiometry. The sample was 162 Emirati students from high school. The researchers used two instruments, which aimed to identify students' understanding and measure students' using of metacognitive strategies. The findings showed that students had a low level of understanding related to the topic of the present study. This study recommended that teachers have to teach students how to use metacognitive strategies to improve their understanding of stoichiometry in particular and chemistry in general.

Also, Al-Naqbi (2014) revealed that male students showed highly significant difference than female students related to students' achievement in chemistry. This study examined the effects of homework on the students' achievement regarding gender in chemistry using quasi-experimental design. The sample was 192 students from 10^{th} grade in UAE. There were 19 homework assignments, and each consisted of 20 items for the experimental groups. The results were collected from the pre- and post- tests scores. The researcher found that homework assignments had a positive effect on the students' achievement in general and on male students in particular. Khalaf (2000) had similar finding when he explored the factors that affect the students' achievement in chemistry. The participants were 204 male students and 252 female students in grade 12 in UAE. The study found that female students had higher scores than male students; therefore, the achievement of female students was better than male students.

Furthermore, Al Zarooni (2014) examined the misconceptions of grade 10 students related to the chemical bonding and types of bonds. The sample was 72 females and 68 males from two public high schools in Dubai. Indeed, the results of this study found that no significant differences regarding gender and the level of understanding. The results indicated that grade 10 students had a variety of misconceptions. Also, the researcher found out that using guided inquiry could minimise the alternative conceptions to improve the understanding of chemical bonds and bonding. The findings had led the researcher to suggest various recommendations that may help teachers and educators to improve and solve students' misconceptions related to chemical equilibrium by using this study as evidence.

On the other hand, Balfakih (2010) focused on the understanding of in-service elementary science teachers about the physical science concepts. This study was conducted at seven schools in the United Arab Emirates (UAE). The instrument was a multiple- choice test that consisted of 22 questions. The test was applied to 126 teachers. The results found that approximately 60% of in-service elementary science teachers had misconceptions about the physical science concepts. This study recommended that teachers must take training programs that designed to improve the teaching and learning processes of science.

2.8 Summary

This chapter presents the findings of previous studies about students' science misconceptions in general and chemical equilibrium in particular. Many factors could impact students' achievement in science, particularly in chemistry such as prior knowledge, textbooks, images and everyday language. This chapter starts with the theoretical framework; the conceptual change theory that is all about how learners' prior knowledge interacts with the surroundings to understand new knowledge.

The reviewed literature above shows that students often have difficulties in chemistry related to chemical equilibrium at school and university levels (Camacho & Good, 1989; Hackling & Garnett, 1985; Özmen, 2008; Voska & Heikkinen, 2000). In additions, the studies generally outline that students have difficulties to understand the chemical equilibrium and its conditions which the dynamic nature of equilibrium are, equilibrium constant, heterogeneous equilibrium, gases equilibrium, and Le- Chatelier principle (Alkan & Benlikaya, 2004; Piquette & Heikkinen, 2005; Yildirim et al., 2011).

Finally, in the UAE context, different results were reported regarding students' misconceptions in science in general and in chemistry in particular, but there were no studies about students’ misconceptions of chemical equilibrium in the context of the UAE.

Chapter 3: Methodology

3.1 Chapter Overview

The purpose of this study is to investigate the students' misconception of chemical equilibrium in three private schools in Al-Ain city. This chapter presents the following sections:

i) The context of the study, which provides information about the context of the study and how the chemical equilibrium concept was introduced in the UAE curriculum.
ii) Population and sample, which is about the participants involved in this study.
iii) Instrumentation – including the results of the pilot study, which discusses the instrument that was used to collect data and how the instrument modified to be valid based on the content of the curriculum.
iv) Data collection procedure, which focuses on the procedure that the researcher followed to collect data, and
v) Data analysis procedure, which explains how the data was collected and the statistical methods that were used to analyse the findings to be reliable.

3.2 Context of the Study

This study measures the level of students' misconception related to the chemical equilibrium for both genders in 12^{th}-grade at three private schools of the Abu Dhabi Department of Education and Knowledge (ADEK). There were over 185 private schools in Emirate of Abu-Dhabi. Only a few private schools are following the Ministry of Education's curriculum because this curriculum enrolled in the

Arabic language. The students from grade one to grade ten are studying different topics in science and humanities.

Upon successful completion of tenth-grade, students are required to select one track either advanced or general studies for grades 11 and 12 based on their achievements and interests. About chemistry in grades 11 and 12, students have to attend four classes per week. Ministry of education provided specific topics in chemistry that covered in each grade level. Students had a background about the concept of equilibrium from another subject in science such as physics, and biology. However, the topic of “chemical equilibrium” is firstly and comprehensively given at first time in 12^{th} grade in chemistry textbook at UAE schools.

3.3 Population and Sample

The population of this study was from private schools that followed the Ministry of Education's curriculum in Al-Ain city. The participants consisted of 206 students. The representative sample was 12^{th}-grade students drawn from three private schools of Abu Dhabi Education Council (ADEC) that follow the Ministry of Education's curriculum. The number of students in each classroom was between 27 to 30 students. There were two tracks in the 12^{th}-grade: general and advanced. Students from 10^{th}-grade should join one track to complete their high school.

The difference between the two tracks was the depth of the scientific knowledge in the science subjects such as math, chemistry, physics, and biology in the advanced track. Students who joined advance track had studied the chemical equilibrium in depth more than general track's students. The sample of this study was only for students in advanced track. Out of the sample, there were 122 female students, and the rest (84) were male students, ranging from 15 to 17 years of age. The Arabic language is the first language for all students, and their academic level was varied from excellent to weak. Thus, they were regarded as homogeneous. Furthermore, the schools were chosen for convenience, as they were near to the researcher's workplace.

Table 1: School-based sample statistics

Schools	Female	%	Male	%	Total
Baraem Al-Ain Private School	34	28	13	15	47
Al-Andalus Private Academy	59	48	26	31	85
Tawam Model Private School	29	24	45	54	74
Total	**122**	**100**	**84**	**100**	**206**

3.4 Instrumentation

The instrument used in the present study was the TISAC to collect data and attain the objectives of the study. TISAC originally contained 13 two-tier multiple-choice questions and developed by Karpudewan et al. (2015) to determine the chemical equilibrium misconceptions and students' reasoning. In this present study, the researcher chose only eight two-tier multiple-choice questions which were consistent with what the students studied. All questions were in the multiple-choice format:

i) The first tier consisted of a content question with three choices.

ii) The second tier consisted of four possible reasons to explain the first tier; three misconceptions and one scientific reason.

In TISAC, each question was evaluated in a different area in chemical equilibrium topic. The first question aimed to indicate the misconceptions related to equilibrium constant when the concentration changed. The second question measured the misconceptions of the equilibrium shift after removing the solid product in the heterogonous equilibrium.

As for the third and fourth questions, they indicated the misconceptions about the approach of equilibrium. In questions 5 and 6, the aim was to apply the Le-Chatelier principle and find all the misconceptions related to this principle. The questions seven and eight were designed to identify the misconceptions about the gas products' concentration at equilibrium in case of changing the concentration of reactants. The participants had informed that the test is not an achievement test and the results would not affect their school grades.

3.4.1 Validity of the Instrument

Content validity established the test validity for this study. The test was translated into the Arabic language to minimise any extraneous factors related to the proficiency in the language. To determine the validity of TISAC test, it was reviewed by a panel of two university professors who are specialized in science education in the College of Education at the UAE University. Furthermore, two experienced chemistry teachers reviewed the test in general, and terminology in particular. Also, it was reviewed by two chemistry teachers in an international school in Al-Ain city. Both chemistry teachers have master's degrees in chemistry and ten years of work experience as a teacher. Each evaluator was provided with a copy of the test in English and Arabic to ensure that the test was correctly translated, and the concepts used in the Arabic version were familiar with the students. The researcher revised the test in the light of the feedback of the panel members to provide the content validity. All recommendations received were used to modify the wording and restate some questions differently according to the Arabic language.

3.4.2 Reliability of the Instrument- Pilot Study

The final version of the test was pilot-tested by twenty-five (n = 25) students who did not participate in the primary sample of this study, and they were from the same school. The researcher conducted reliability analyses for TISAC. The reliability measured the ability of consistently assessing what is targeted to be assessed (Aoude & Fadi, 2015). The reliability coefficient was found to be 0.70 (Table 3.2), which was accepted for this study.

Table 2: Final test reliability

Reliability Statistic	
No. of Items	16.00
Cronbach’s Alpha of the pilot study	0.70
Cronbach’s Alpha of the sample	0.65

The reliability of the TISAC scores as measured by Cronbach’s Alpha was found to be (0.65). The lower value of Alpha could be referred to the small number of items and participants.

3.5 Data Collection Procedure

Initially, the researcher selected three schools for convenience, as they were near to the researcher's workplace in Al-Ain city. The researcher visited the schools and explained to the administration about the study because ADEC required having a permission letter from each selected school to obtain the necessary letter to access the schools and start the study to collect the data and information.

In the next step, the researcher considered the timing regarding the application of the study, which was to be in the third term of the academic year 2016-2017. This is due to the topic of chemical equilibrium being taught in the third term. The students had one period (45 minutes) to respond to the questions in the test. They had been informed that the results of this study would not affect their school grades and the test was not an achievement test. Therefore, they were asked to focus on their answers to provide accurate findings that answer the research questions. Also, students' confidentiality was respected, as individual participants' performance was not reported using participants' names.

3.6 Data Analysis Procedure

The quantitative data for this study were analysed using the Statistical Package for Social Sciences (SPSS) software version 24. The students' answers of TISAC were converted into numbers to find the descriptive statistics (frequencies, mean, and standard deviation) and inferential statistics (*t*-test). The students earned one point for each correct answer whether in the first or second tier; and zero when otherwise. For each question, the total scores of the content and reason points were taken together to classify students' understanding into four categories: scientific knowledge, misconception, lucky guess, and lack of knowledge.

Table 3: Decision matrix for classifying the level of understanding

1^{st} Tier	2^{nd} Tier	Total Score	Differences between 1^{st} tier and 2^{nd} tier	Categories
Correct (1 point)	Correct (1 point)	2	0	Scientific Knowledge
Correct (1 point)	Incorrect (0 point)	1	1	Misconception
Incorrect (0 point)	Correct (1 point)	1	-1	Lucky guess
Incorrect (0 point)	Incorrect (0 point)	0	0	Knowledge lack

As shown in Table 3.3, students who had scientific knowledge or lack of knowledge, they had total score = 2 or total score = 0, respectively. While the differences between 1^{st} tier and 2^{nd} tier were indicated to the students who had a misconception or a lucky guess, when the difference =1 or the difference = -1, respectively.

The students' responses are classified into four categories that reflect the levels of understanding as follows:

i) *Scientific knowledge*: If the students selected the correct answers in both tiers.
ii) *Misconceptions*: if the students selected correct content answer in the first tier and incorrect reason in the second tier.
iii) *Lack of knowledge*: if the student has selected incorrect answers in both tiers.
iv) *Lucky guess*: if the student selected incorrect content answer and correct reason.

In summary, this chapter provides information related to the methodology was used in this study including a description of the participants and how they were selected, the instrument was used and how it was validated. It also explains procedures were followed to collect data, and how the collected data were analysed to answer the research questions.

Chapter 4: Results

4.1 Chapter Overview

This chapter presents and discusses the results of the collected data of this study using a two-tier test, which was the Test to Identify Students' Alternative Conceptions (TISAC). This instrument was used to identify the misconceptions of the chemical equilibrium among 12th-grade students. Quantitative data collected by using eight questions based on TISAC model to answer the following research questions:

i) *What are the levels of understanding of 12th-grade students in chemical equilibrium*?

ii) *What is the nature of misconceptions brought by 12th-grade students about the main four concepts related to chemical equilibrium*?

iii) *What is the impact of gender on the students understanding of chemical equilibrium*?

4.2 Research Question 1: About the level of understanding

What are the levels of understanding of 12th-Grade students in chemical equilibrium?

To answer this question among 12th-grade students, Table 4 shows the number and percentage of students who had the correct answer in the first tier (content choice) and correct combination (content and reason choice) for each question. Also, Table 4 shows that not all students were satisfied with their understanding of the chemical equilibrium concept. In the first tier, the range of correct content choice was between 33% and 71.8%, while the range of correct combination was decreased to (9.2% and 50.5% respectively).

Table 4: The percentages of correct content and the correct combination

Item	Correct content Choice			Correct combination choice		
	Female	Male	% of students	Female	Male	% of students
1	77	54	63.6	47	29	36.9
2	26	42	33.0	20	32	25.2
3	74	49	59.7	53	40	45.1
4	43	47	43.7	26	38	31.0
5	46	19	31.6	09	10	09.2
6	95	53	71.8	70	34	50.5
7	61	25	41.7	51	17	33.0
8	54	21	36.4	36	14	24.3

Tables 5 to 12 showing students' responses to each item in TISAC. The results based on calculating the number and percentage of students in each category for each item.

- **Item 1:** The following hypothetical reaction reaches equilibrium at 25ºC:

$$A_{(g)} + B_{(g)} \rightleftharpoons C_{(g)} + D_{(g)}$$

Once equilibrium has been reached, the concentration of C is increased by the addition of more C. *Assume that the temperature remains constant, which of the following could be said about the numerical value of the equilibrium constant*?

i) The correct content answer: (c) Remains unchanged.

ii) The correct reason: (3) The ratio between products' concentrations and reactants' concentrations is constant at constant temperature.

Table 5 shows that thirty-six percent of students (n=76) answered both tiers correctly, therefore, they had scientific knowledge. However, 26.7% of students (n=55) had a partial understanding as misconceptions by selecting a correct content answer, and incorrect reason and 28.6% of students (n=59) had lack of knowledge by answering both ties incorrectly. The rest was represented 7.8% of students (n=16) who had an incorrect content answer and correct reason by guessing.

Table 5: Distribution of students of item one in TISAC into four categories

Item One	Female	Male	% of students
Scientific knowledge	47	29	36.9
Misconception	30	25	26.7
Lucky guess	11	05	07.8
Lack of knowledge	34	25	28.6
Total	**122**	**84**	**100.0**

- **Item 2:** Limestone decomposes to form quicklime and carbon dioxide as follow:

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$$

What can we say about any equilibrium shift after removing some solid $CaCO_3$ from the equilibrium mixture?

i) The correct content answer: (a) Shift to the reactants' side.

ii) The correct reason: (3) CO_2 and CaO react to form more $CaCO_3$ according to Le Chatelier principle.

In Table 6, the highest percentage was 52% (n=108) that represented the students who selected incorrect answers for both tiers, and they represented as students had lack of knowledge. However, the students who had scientific knowledge was represented 25% of students (n=52), that was referred to the low level of understanding in this item. Only about 7% of students (n=16) were able to answer only first-tier correctly, while about 15% of students (n=30) were able to guess the correct reason without a correct content answer.

Table 6: Distribution of students of item two in TISAC into four categories

Item Two	Female	Male	% of students
Scientific knowledge	20	32	25.2
Misconception	06	10	07.8
Lucky guess	18	12	14.6
Lack of knowledge	78	30	52.4
Total	**122**	**84**	**100**

- **Item 3:** Carbon monoxide and hydrogen react according to the following equation.

$$CO_{(g)} + 3H_{2\,(g)} \rightleftharpoons CH_{4\,(g)} + H_2O_{(g)}$$

When 0.02 M CO and 0.03 M H_2 are introduced into a vessel at 800K and allowed to come to equilibrium, what can we say about the rate of reverse and forward reactions at equilibrium?

i) The correct content answer: (a) The rates are equal.

ii) The correct reason: (2) The rates of the forward and reverse reactions are equal when the system reaches equilibrium.

Table 7 shows that the majority of students were under scientific knowledge category (45%; n=93) that who answered both tiers correctly, that showed a high level of understanding in this item. Thirty-three percent of students (n=68) who answered both tiers incorrectly and that represented the students who demonstrate lack of knowledge. There was also 15% (n=30) of students had misconceptions, and only 7% (n=15) of students got the correct reason without correct content answer by guessing.

Table 7: Distribution of students of item three in TISAC into four categories

Item Three	Female	Male	% of students
Scientific knowledge	53	40	45.1
Misconception	21	09	14.6
Lucky guess	11	04	07.3
Lack of knowledge	37	31	33.0
Total	**122**	**84**	**100.0**

- **Item 4:** In the first step of the Ostwald process for the synthesis of nitric acid, ammonia is oxidised to nitric oxide by the reaction:

$$4NH_{3(g)} + 5O_{2\ (g)} \rightleftharpoons 4NO_{\ (g)} + 6H_2O_{\ (g)}$$

H = -905.6 kJ/mol. How does the equilibrium constant vary with an increase in temperature?

i) The correct content answer: (c) Decreases.

ii) The correct reason: (2) The equilibrium will shift to the left with an increase in temperature.

The results of item four are presented in Table 8 that shows most of the students had lack of knowledge because the percentage is above 50% (n=108) of the students who had incorrect answers in both tiers. While only 31% (n=64) of students provided correct answers in both tiers and about 12% of the students (n=26) had misconceptions by providing a correct content answer and incorrect reason.

Table 8: Distribution of students of item four in TISAC into four categories

Item Four	Female	Male	% of students
Scientific knowledge	26	38	31.1
Misconception	17	09	12.6
Lucky guess	05	03	03.9
Lack of knowledge	74	34	52.4
Total	**122**	**84**	**100**

- **Item 5:** *If you have a 0.5 M solution of sodium dichromate* ($Na_2Cr_2O_7$), *in which the following equilibrium is established*:

$$\underset{\text{Yellow}}{2CrO_4^{2-}{}_{(aq)} + 2H^+{}_{(aq)}} \rightleftharpoons \underset{\text{Orange}}{Cr_2O_7^{2-}{}_{(aq)}} + H_2O_{(l)}$$

moreover, you add ten mL of 0.5 M solution of sodium dichromate to the original solution what would you observe?

i) The correct content answer: (a) The solution becomes yellow.

ii) The correct reason: (1) To counteract the increased amount of $Cr_2O_7{}^{2-}$ as the system will form more CrO_4^{2-}.

Table 9 shows the percentage of students who classified as not having any knowledge is above 52% of the students (n=109). However, about 22% of students (n=46) had misconceptions about this item. There was only 9% of the students (n=19) had scientific knowledge. Therefore, the results showed that the students had a low level of understanding related to this item.

Table 9: Distribution of students of item five in TISAC into four categories

Item Five	Female	Male	% of students
Scientific knowledge	09	10	09.2
Misconception	37	09	22.3
Lucky guess	22	10	15.5
Lack of knowledge	54	55	52.9
Total	**122**	**84**	**100**

- **Item 6:** Consider the following reversible reaction that is in a state of equilibrium:

$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)},\ \Delta H = -\ 92.4\ kJ/mole$$

If the temperature of the system is increased, the equilibrium position will shift.

i) The correct content answer: (a) Shift to the left.

ii) The correct reason: (2) If the temperature is increased, more reactants are formed.

The results of item 6 show that 70% of the students (n=148) had a correct content answer, while only 50% of them (n=104) provided the correct reason and the remaining had misconceptions because of their incorrect reason.

As shown in Table 10, sixteen percent (16%; n=33) of the students had lack of knowledge, and twelve percent (12%; n=25) of the students were provided with the correct reason by guessing.

Table 10: Distribution of students of item six in TISAC into four categories

Item Six	Female	Male	% of students
Scientific knowledge	70	34	50.5
Misconception	25	19	21.4
Lucky guess	09	16	12.1
Lack of knowledge	18	15	16.0
Total	**122**	**84**	**100**

- **Item 7:** Suppose that 0.30 mol PCI_5 is placed in a reaction vessel of volume 1000 mL and allowed to reach equilibrium with its decomposition products: phosphorus trichloride and chlorine at:

  250ºC, when K_{eq}= 1.8 for $PCI_{5\ (g)} \rightleftharpoons$ PCI3(g) + CI2(g)

  What can we say about the concentration of the PCI_3 gas and CI_2 gas at equilibrium?

  i) The correct content answer: (a) Higher than 0.30 M

  ii) The correct reason: (3) Phosphorus pentachloride decomposes to an extent less than 100% to produce phosphorus trichloride and chlorine.

Table 11 shows that 33% (n=68) of the students had scientific knowledge by providing the correct content answer and support their scientific understanding by providing the correct scientific reason. While above 8% of the students (n=18) had only the correct content answer that supports their partial understanding. However, above 50% of the students (n=120) had an incorrect content answer, which showed a low level of understanding in this item.

Table 11: Distribution of students of item seven in TISAC into four categories

Item Seven	Female	Male	% of students
Scientific knowledge	51	17	33.0
Misconception	10	08	08.7
Lucky guess	35	29	31.1
Lack of knowledge	26	30	27.2
Total	**122**	**84**	**100**

- **Item 8:** Calcium carbonate decomposes to form calcium oxide and carbon dioxide according to the equation:

$$CaCO_{3\,(s)} + heat \rightleftharpoons CaO_{(s)} + CO_{2\,(g)}$$

After the system reaches equilibrium in a closed container, extra solid $CaCO_3$ is added to the equilibrium mixture. *What will happen to the concentration of carbon dioxide after addition*?

i) The correct content answer: (a) increases.

ii) The correct reason: (2) Because CaCO3 is added to the reactants' side, equilibrium will shift to the products' side.

Table 12 shows that most of the students (above 50%; n=106) were unable to answer this item correctly. Only about 35% of students (n=75) were able to provide the correct content answer, while 24% of them (n=50) were able to provide the correct reason and reflect their scientific understanding. More than 50% of students (n= 106) failed to select the correct content answer or the scientific reason. This was shown the levels of understanding of students were low related to this item.

Table 12: Distribution of students of item eight in TISAC into four categories

Item Eight	Female	Male	% of students
Scientific knowledge	36	14	24.3
Misconception	18	07	12.1
Lucky guess	12	13	12.1
Lack of knowledge	56	50	51.5
Total	**122**	**84**	**100**

4.3 Research Question 2: About nature of misconceptions

What is the nature of misconceptions possessed by students related to chemical equilibrium in four main concepts: the equilibrium constant, approach to equilibrium, heterogeneous equilibrium systems and Le-Chatelier principle?

Items 1 and 4 asked students about how the numerical value of the equilibrium constant changes with an increase in concentration and temperature respectively. Table 13 shows the results of items 1 and 4. The percent of misconceptions in this concept was about 39%. Also, the main misconception of students in item one is that the equilibrium constant remains unchanged even if the concentration of the products increased, which was held by 26 students. While in item four, the main misconception is that the equilibrium constant did not affect whether the reaction is endothermic or exothermic, this was held by 13 students.

Table 13: Nature of the misconception in the equilibrium constant

Topics evaluated	Items	Misconception statement	n	% of students per item	% of students per topic
Equilibrium Constant	1	[1] The rate of reverse reaction increases, and the rate of the forward reaction decreases.	17	26.7	39.3
		[2] The rate of reverse reaction increases and the rate of forwarding reaction stay the same.	12		
		[4] The concentration of the products has been increased.	26		
	4	[1] An increase in temperature always increases the numerical value of K_{eq}	07	12.6	
		[2] Because the reaction is exothermic, the concentration of product increases.	06		
		[4] Whether the reaction is endothermic or exothermic does not affect the K_{eq}	13		

Examining the results presented in Table 14, which were about the misconceptions related to heterogeneous equilibrium systems, which had the lowest percentage of misconceptions (20%) out of all evaluated area. This concept was tested in items two and eight. The main misconception was held by 13 students who thought that the concentrations of pure solids in a given volume are constant at equilibrium system.

Table 14: Nature of the misconception in the heterogeneous equilibrium

Topics evaluated	Items	Misconception statement	n	% of students per item	% of students per topic
Heterogeneous equilibrium systems	2	[1] The amount of $CaCO_3$ is increased in the system, and a new equilibrium is established.	04	7.8	19.9
		[2] Because $CaCO_3$ is solid, removing it does not affect the equilibrium.	09		
		[4] The amount of solid $CaCO_3$ removed is not known.	03		
	8	[1] Increasing the amount of $CaCO_{3\ (s)}$ that is at equilibrium causes more dissolved ions to be produced.	10	12.1	
		[4] The concentrations of pure solids, that is, the quantities in a given volume or densities, are constant.	13		
		[3] Because $CaCO_{3\ (s)}$ is added to reactants' side, equilibrium will shift the reactants' side.	02		

The results of items three and seven were shown in Table 15. These items were evaluated the misconception related to the approach to equilibrium, and the percent of misconception in this concept was about 23%. The main misconception was that the concentration of reactants was directly proportional to the concentrations of products.

Table 15: Nature of the misconception in the approach to equilibrium

Topics evaluated	Items	Misconception statement	n	% of students per item	% of students per topic
Approach to equilibrium	3	[1] Forward reaction goes to completion before the reverse reaction starts.	01	14.56	23.26
		[2] As time passes, the concentrations of products increase.	08		
		[4] At the beginning, the concentrations of the reactants are higher than the concentrations of products.	21		
	7	[1] Concentrations of all species in the reaction mixture are equal at equilibrium.	05	08.70	
		[2] All the phosphorus pentachloride turns into the products.	07		
		[4] Because the total moles of the products are higher than the reactants' ones.	06		

Finally, Table 16 showed the students' misconceptions to items five and six, which were related to the application of Le-Chatelier principle. In this concept, students showed the highest percent of misconceptions compared with other concepts evaluated, which was 47%. The students were asked to apply Le-Chatelier principle when the concentration (item 5) and temperature (item 6) increased. The main misconception was that when the volume increases, the concentration would be the same. This misconception was held by 26 students in item5. However, there were two misconceptions related to item 6 i) increasing in the temperature formed more products or could not affect the system at equilibrium, and ii) 20 students held each misconception.

Table 16: Nature of the misconception in the application of Le-Chatelier principle

Topics evaluated	Items	Misconception statement	n	% of students per item	% of students per topic
Application of Le-Chatelier	5	[2] There will be more collisions between particles of $Cr_2O_7^{2-}{}_{(aq)}$ and $H_2O_{(l)}$.	12	26.20	47.55
		[3] There is no change in the concentration of any species	26		
		[4] Because of increase in $Cr_2O_7^{2-}$, Q will be higher than K_{eq}	08		
	6	[1] When the temperature is increased, more products form.	20	21.35	
		[3] When the temperature is changed, whether the reaction is endothermic or exothermic does not affect the direction of the equilibrium shift.	04		
		[4] Temperature changes do not affect the system that is at equilibrium.	20		

4.4 Research Question 3: About impact of student gender

What is the impact of gender on the students understanding of chemical equilibrium?

The third research question is aimed to examine the influence of gender on the student understanding of the chemical equilibrium. To answer this question, mean and standard deviation of female and male students were calculated and presented in Table 17. The results are presented related to whether or not the gender might affect the level of the students' understanding was based on comparing the responses between female and male. As shown in Table 17, both gender showed a similar level of understanding as showed by the similar mean scores and standard deviation.

Table 17: Student understanding of both gender in the chemical equilibrium

	Mean		Std. Deviation		*t*-test
Total Score	Female	Male	Female	Male	
	7.5	7.3	3.1	3.0	-0.3

To test for any significant differences between genders, t-test was calculated. There was no significant difference found between female and male misconceptions related to chemical equilibrium.

Chapter 5: Summary, Discussion, and Recommendations

5.1 Chapter Overview

This chapter presents summary and discussion of the results presented in Chapter 4 to explore the chemical equilibrium misconceptions among 12^{th}-grade students. This chapter is divided into five sections: First section summaries this study, the second section discusses the results of each research question and compares them with the results obtained from the previous literature. Finally, the chapter further provides recommendations that lead to modify and develop meaningful goals for the educational process.

5.2 Research Question One

(*What are the levels of understanding of 12^{th}-grade students in chemical equilibrium?*)

Item 1 in TISAC is concerned about the constant equilibrium concept; the highest percentage of students was 36.9% who had scientific knowledge. The students showed their scientific understanding that the numerical value of the equilibrium constant could not change with the increase of concentration of the products.

Also, the students showed a similar level of understanding related to misconception and lack of knowledge. The students who had misconceptions explained that the equilibrium constant remains unchanged because of the increasing of the rate of reverse and forward reactions or the concentration of products. While the students who had lack of knowledge explained that the numerical value of the equilibrium constant changes with the changing of the concentration. These findings support the findings of Voska and Heikkinen (2000) who found that 40% of the samples had misconceptions related to this concept. Also, this finding was in line with other findings such as Karpudewan et al. (2015) who indicated that students were not able to explain their answers and they were not able to prove their full understanding. This may be due to the equilibrium constant that expressed the concentrations of products and reactants.

Item 2 examined the heterogeneous mixtures after removing some of the solid reactants. Half of the students had lack of knowledge related to this item. This could be due to the difficulties of understanding of heterogeneous mixtures at equilibrium that students had. This finding is consistent with the findings reported in the studies of Piquette and Heikkinen (2005) and Yildirim et al. (2011). They enunciated that students face difficulties to understand heterogeneous mixtures and it is one of the most challenging concepts related to the topic of chemical equilibrium.

With regards to the third item that was related to the approach towards equilibrium, the highest percentage was 45% of students who had scientific knowledge. This shows that students had the basic understanding of chemical equilibrium in which the rates of reverse and forward reactions are equal at equilibrium. When the two tiers of the test were combined, this item represented the second highest percentage of students' misconceptions. This indicates that most of the students could explain their answer related to the approach to equilibrium. As indicated by Sampath Kumar (2016), students had the lowest percentage of misconceptions in the approach to equilibrium, and hence this reflected the highest level of understanding.

As for the fourth item which is concerned with the equilibrium constant similar to an item on, however; it is testing the effect of temperature on the equilibrium constant. More than half of the students had lack of knowledge in this item. They thought that the equilibrium constant would increase or be unchanged with the increase of temperature. This may be due to the difficulty that students had in understanding the concept of the equilibrium constant and how it is related to the temperature. However, Karpudewan et al. (2015) supported that students faced difficulties regarding the equilibrium constant. Also, the authors concluded that the students had lack of understanding related to equilibrium constant.

The fifth and sixth items were related to the application of the Le-Chatelier principle. The results indicated that more than 50% of the students had no understanding in item five, which was reported as lack of knowledge. This shows that students could not properly apply the Le-Chatelier principle, when the concentration of one of the products was changed by adding more. Also, the findings showed that more than 50% of students had scientific knowledge. Therefore, this indicates that students could apply the Le-Chatelier principle when the temperature increases. It could be due to the students' understanding of exothermic and endothermic reactions. These findings are consistent with the works of Hackling and Garnett (1985) and Karpudewan et al. (2015) who found that students had limited understanding and ability to apply Le-Chatelier principle when the temperature or concentration changed.

With regards to the seventh item which was about the approach of equilibrium that discusses the concentration of products in the gas state after increasing the concentration of reactants in a constant volume. The results showed that students have approximately similar percentages in three levels of understanding, which are scientific knowledge, lucky guessing, and lack of knowledge. This indicates that students might not have a clear understanding of this concept. Most of the students thought that the total moles of the reactants and products are equal at equilibrium. This finding is consistent with the findings of Ozman (2008), that states that the most of misconceptions regarding the approach to equilibrium.

The eighth item was about the increasing of concentration of reactants in constant volume in the heterogenous mixture. Half of the students had lack of knowledge in this item. This indicates that students had an unclear understanding of how to re-establish a new equilibrium to counteract the changing. Most of the students thought that the concentrations of products remain the same because the concentrations at equilibrium in a given volume are constant. This concept is considered as one of the problematic concepts related to chemical equilibrium by students according to Piquette and Heikkinen (2005) and Karpudewan et al. (2015).

5.3 Research Question Two

(*What is the nature of misconceptions possessed by students related to chemical equilibrium in four main concepts: the equilibrium constant, approach to equilibrium, heterogeneous equilibrium systems and Le-Chatelier principle?*)

The results of the current study suggested some misconceptions related to the four main concepts discussed in this study by the 12^{th}-grade students. As the results have shown, the highest percentage of misconceptions was 47.55% which was found to be related to the application of Le-Chatelier principle. The common misconception related to this concept was that there is no change in the concentration of any species. In the literature, Solomonidou and Stavridou (2001) and Ozman (2008) reported the same misconception which is that the equilibrium will not change because the additional amount had the same concentration. However, two misconceptions were held by the same number of students. The misconceptions were related to the effects of temperature change on a system at equilibrium, if it changes the direction of the equilibrium or does not affect the equilibrium at all. Similar misconceptions were determined by Voska and Heikkinen (2000) and Ozman (2008). Both studies assumed that students could not understand the chemical reaction at equilibrium when the temperature of the system increased. That could help the students to determine the new shifting of equilibrium after the disturbance by changing the conditions.

In the present study, the second highest percentage of misconceptions was related to the equilibrium constant, and that was analysed in two items, which were item 1 and item 4. The main misconception in item one was that the numerical value of equilibrium constant depends on the number of reactants and products. However, the main misconception in item four which is related to this concept was that whether the reaction is endothermic or exothermic does not affect the equilibrium constant. Similar misconceptions were reported in the related literature (Voska & Heikkinen, 2000; Ozman, 2007). For example, Voska and Heikkinen (2000) reported that the highest percentage of misconceptions was related to the effects of temperature change on a system at equilibrium and it was 65%.

In the approach to equilibrium concept, the main misconception was that the rate of forwarding reaction is greater than the reverse reactions because the concentrations of the reactants are greater than the concentration of products at the beginning. However, the number of students who had other misconceptions was very small compared to the main misconception in the approach to equilibrium. Hackling and Garnett (1985) revealed that most of the students were unable to explain their understanding that related to the approach to equilibrium. This finding also supports the work of Sampath Kumar (2016) who stated that students had the lowest percentage of misconceptions in the approach to equilibrium concept. This, in turn, reflects a high level of understanding.

Also, the lowest percentage of misconception was 19.9%, which was related to heterogeneous mixtures at equilibrium. This could be because the concept of heterogeneous mixtures at equilibrium was easy to understand it by students. The similar findings were identified in two previous studies (Voska & Heikkinen, 2000; Ozman, 2008). Also, Özmen (2008) found that only 38% of students had misconceptions according to the heterogeneous mixtures at the chemical equilibrium.

5.4 Research Question Three

(*What is the impact of gender on the students understanding of chemical equilibrium?*)

The results showed that no significant differences were found in misconceptions between male and female students. Data analysis showed that female and male students had a similar level of understanding because their mean scores were almost similar, which were 7.3 for females and 7.5 for males. These results could be due to many reasons, for example, both genders was taught using same educational resources, or they have the same school environment, and the same chemistry teacher. Findings of many previous studies were consistent with this finding such as Can and Boz (2011) and Kennis (2005). The previous studies concluded that there were no significant differences across males and females when solving problems and explaining their reasons. Within the UAE context, Al Zarooni (2014) found that no significant differences across gender were related to the chemical bond. Also, this finding is supported by Al-Rubayea (1996), Greenfield (1996) and Stafslien (2001) who found that no significant differences in students' responses across gender in the understanding of scientific concepts.

On the other hand, other studies found that female students had better achievement than male students such as Khalaf (2000). On the other hand, Gray (2006), Greenfield (1996), and Stafslien (2001) reported that male students were trying to explain their answers either correct or incorrect and they had better performance than female students in science and mathematical achievement.

5.5 Summary

This study is concerned with the chemical equilibrium misconceptions of 12^{th}-grade female and male students using a two-tier diagnostic test. It seeks to answer the following research questions, which are:

1) *What are the levels of understanding of 12th-grade students in chemical equilibrium*?
2) *What is the nature of misconceptions possessed by students related to chemical equilibrium in four main concepts: the equilibrium constant, approach to equilibrium, heterogeneous equilibrium systems and Le-Chatelier principle*?

3) *What is the impact of gender on the students understanding of chemical equilibrium*?

The sample was 206 students (84 males and 122 females) in three private schools of Abu Dhabi Education Council (ADEC) in Al-Ain city. All participants were in advance track, and they were in the age range of 15 to 17 years. This study was conducted in the third semester of the academic year 2016 / 2017.

The researcher used TISAC, which consisted of two-tier multiple choice to collect data. Each question in TISAC had the first tier that consisted of a content question with three choices and the second tier consisted of four possible reasons to explain the first tier; three misconceptions and one scientific reason. TISAC had eight items, and every two questions assessed the students understanding in one of the four concepts related to chemical equilibrium. The concepts evaluated in this study were: Dynamic nature of equilibrium, equilibrium constant, gases equilibrium, and Le-Chatelier principle.

The data were analysed using the Statistical Package for Social Sciences (SPSS). The analysis included descriptive statistics (frequencies, mean, and standard deviation) and inferential statistics (t-test). Also, the results of all questions found that the students had four different levels that reflect their knowledge related to chemical equilibrium, which was scientific knowledge, misconception, lucky guessing, and lack of knowledge. The findings generated the discussion are referred to in the following questions:

5.6 Recommendations

The results showed that students in both genders had difficulties in the chemical equilibrium concepts. This study was conducted at only three private schools in Al-Ain city in UAE. The current study provides evidence that come up with some recommendations related to policymakers and curriculum developers, science and chemistry teachers, students, and researchers for future researchers. The study suggests the following recommendations:

1) Policy makers: should be aware of students’ misconceptions to design the chemistry curriculum. This can be done by making learning outcomes, textbooks, and teaching methods based on student-centred learning.
2) Curriculum developers: should take students’ misconceptions into account while developing the chemistry curriculum. They should relate the curriculum to student personal experience and real-life applications to enhance the level of understanding. The curriculum has to increase the students’ achievement by critical thinking questions.
3) Science and chemistry teachers: should be conversant about the misconceptions that students may bring to class, which were related to chemical equilibrium. They also should know the best teaching instructions to correct the misconceptions of students. Once the teachers identified the students’ misconceptions, they can fix their student's misconceptions by having the scientifically accepted concept. For this reason, teachers should develop diagnostic instruments to improve the chemistry learning such as a two-tier multiple-choice instrument. However, Teacher should take into account the students’ prior knowledge and misconceptions. Teachers should

be trained about conceptual change and constructivism theories and their application to overcome the students' misconceptions described in the previous section. Also, Teachers should improve their motivational, instructional, and management strategies to sustain their professional development.

4) Teachers' university preparation program: teachers should be trained about conceptual change and constructivism theories and their application to overcome the students' misconceptions.
5) Future researchers: this study also recommended that future studies should be undertaken on a large scale about the chemical equilibrium concepts and their misconceptions. For example, more research is needed to increase the students' level of understanding in this topic by studying the factors that may impact on students' understanding. Furthermore, future researchers may need to focus on the teaching methods that can help teachers and students to overcome their misconceptions. This study could be conducted again to include more schools over the private and public sectors and using mixed research methods.

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Appendices

Appendix A: TISAC

أسئلة اختيار من متعدد عن درس الاتزان الكيمائي

اسم المدرسة:

أنثى / ذكر

التعليمات:
تحتوي هذه الصفحات على 8 أسئلة عن الاتزان الكيميائي.
كل سؤال له جزآن: ج (1) اختيار من متعدد للإجابة عن السؤال، ج(2) اختيار من متعدد لذكر السبب.
تذكر أنه يجب عليك اختيار إجابة واحدة فقط في الجزء الأول، وإجابة واحدة فقط في الجزء الثاني لكل سؤال.
يجب عليك قراءة كل سؤال ومجموعة الأسباب المحتملة بتأن.
ليست هناك أي نتائج أو إجراءات متعلقة بهذا الاختبار.
الاختبار لا يعدُّ اختبار تحصيلي.
نتائج الاختبار لن تؤثر في نتائج المدرسة.

1. بافتراض أن التفاعل التالي في حالة اتزان عند درجة حرارة الغرفة $25^{O}C$، ما تأثير زيادة تركيز الناتج C على القيمة العددية لثابت الاتزان عند نفس درجة الحرارة نفسها؟

$$A_{(g)} + B_{(g)} \rightleftharpoons C_{(g)} + D_{(g)}$$

(a) يقل
(b) يزداد
(c) يبقى ثابتاً

السبب:
(1) لأن سرعة التفاعل العكسي تزداد، في حين تنخفض سرعة التفاعل الأمامي.
(2) لأن سرعة التفاعل العكسي تزداد، وسرعة التفاعل الأمامي تبقى ثابتة.
(3) لأن نسب تراكيز المواد المتفاعلة، و المواد الناتجة ثابتة عند درجة حرارة ثابتة.
(4) لأن تركيز المواد الناتجة ازداد.

2. عند تفاعل تحلل الحجر الجيري ينتج الجير وثاني أكسيد الكربون كما هو موضح في التفاعل المتزن التالي:

$$CaCO_{3\,(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$$

ماذا يمكن أن تقول عن اتجاه إزاحة التفاعل المتزن بعد إزالة بعض من $CaCO_3$؟

(a)سيتجه التفاعل باتجاه المتفاعلات.
(b) لن يتغير اتجاه الاتزان.
(c) لا يمكن التنبؤ بالاتجاه.

السبب:

(1) ستزداد كمية $CaCO_3$ في النظام و ينشأ اتزان جديد.
(2) لأن $CaCO_3$ في حالة صلبة، ولن يؤثر إزالته في الاتزان.
(3) CaO و CO_2 سيتفاعلان لإنتاج المزيد من $CaCO_3$ حسب مبدأ لشواتييه.
(4) كمية $CaCO_3$ التي تم إزالتها غير معروفة.

3. يتفاعل أول أكسيد الكربون مع الهيدروجين كما هو موضع في التفاعل التالي:

$$CO_{(g)} + 3H_{2\,(g)} \rightleftharpoons CH_{4\,(g)} + H_2O_{(g)}$$

كيف يمكن أن تصف سرعة التفاعل الأمامي والتفاعل العكسي في حالة الاتزان بعد إضافة 0.02M من CO و3M0.0 من H_2 عند درجة حرارة 800K؟

(a) السرعتان متساويتان.
(b) سرعة التفاعل الأمامي أسرع من التفاعل العكسي.
(c) سرعة التفاعل العكسي أسرع من التفاعل الأمامي.

السبب:

(1) لأن التفاعل الأمامي ينتهي قبل بدأ التفاعل العكسي.
(2) لأن سرعتي التفاعل الأمامي والعكسي متساويتان في حالة الاتزان.
(3) لأن تركيز المواد الناتجة مع مرور الوقت يزداد.
(4) لأن تركيز المواد المتفاعلة مع بداية التفاعل، أكبر من تركيز المواد الناتجة.

4. تتمثل الخطوة الأولى من عملية وستتوالد لتركيب حمض النتريك، بتأكسد الأمونيا لإنتاج أكسيد النتريك، كما هو موضح في التفاعل التالي: $4NH_{3(g)} + 5O_{2\,(g)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$, H = -905.6 kJ/mole كيف يتغير ثابت الاتزان عند ارتفاع درجة الحرارة؟

(a) يبقى ثابتاً
(b) يزداد
(c) يقل

السبب:

(1) القيمة العددية لثابت الاتزان K_{eq} دائما تزداد بارتفاع درجة الحرارة.
(2) بارتفاع درجة الحرارة؛ سيتجه التفاعل باتجاه اليسار.
(3) سيزداد تراكيز النواتج؛ لأن التفاعل طاردا للحرارة.
(4) إن كان التفاعل طارداً للحرارة أو ماصاً للحرارة، فلذلك لا يؤثر على ثابت الاتزان K_{eq}.

5. إذا كان لديك محلول من ثاني كرومات الصوديوم بتركيز 0.5M وتحقق الاتزان من خلال المعادلة التالية:

$$2CrO_4^{2-}{}_{(aq)} + 2H^+ \rightleftharpoons Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)}$$

اصفر **برتقالي**

ثم أضفت 10mL من محلول من ثاني كرومات الصوديوم بتركيز 0.5M إلى المحلول الأصلي، ماذا ستلاحظ؟

(a) يصبح المحلول أصفر اللون.
(b) يصبح المحلول برتقالي غامق.
(c) يبقى المحلول كما هو بدون تغيُّر.

السبب:

(1) سيتجه النظام إلى إنتاج المزيد من $CrO_4^{2-}{}_{(aq)}$، للتغلب على زيادة كمية $Cr_2O_7^{2-}{}_{(aq)}$

(2) ستزداد التصادمات بين جزيئات الماء و $Cr_2O_7^{2-}$.

(3) لا يوجد أي تغيير في التراكيز.

(4) قيمة Q ستكون أكبر من قيمة K_{eq} ، بسبب الزيادة في $Cr_2O_7^{2-}$.

6. أمعن النظر في التفاعل العكسي التالي وهو في حالة الاتزان: $N_{2\,(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3\,(g)}$, H = -92.4 KJ/mole إذا ارتفعت درجة حرارة النظام، اتجاه الاتزان سوف

(a) يتجه إلى اليسار.

(b) يتجه إلى اليمين.

(c) لن يتغير.

السبب:

(1) تزداد النواتج بارتفاع درجة الحرارة.

(2) تزداد المتفاعلات بارتفاع درجة الحرارة.

(3) عندما تتغير درجة حرارة للتفاعل سواء كان ماصاً للحرارة او طارداً لن يتأثر اتجاه الاتزان الكيميائي.

(4) التغير بدرجة الحرارة لن يؤثر على نظام في حالة الاتزان.

7. افترض أن 0.30 mol من PCl_3 وضع في وعاء حجمه 1000 mL ليصل الى حالة الاتزان، ثم تفكك إلى ثالث كلوريد الفوسفور وكلورين عند درجة حرارة 250 C عند $K_{eq} = 1.8$, $PCl_{5\,(g)} \rightleftharpoons PCl_{3\,(g)} + Cl_{2\,(g)}$، فكيف يمكنك أن تصف تركيز غاز PCl_3 وغاز Cl_2 في حالة الاتزان؟

(a) اكثر من 0.30 M

(b) اقل من 0.30 M

(c) يساوي 0.30 M

السبب:

(1) تبقى كل التراكيز في خليط التفاعل متساوية في حالة الاتزان.

(2) كل كمية PCl_5 تتحول إلى النواتج

(3) تفكك PCl_5 إلى أقل من 100% لإنتاج Cl_2 و PCl_3

(4) لأن مجموع المولات للنواتج أكبر من المتفاعلات

8. تتفكك كربونات الكالسيوم إلى أكسيد الكالسيوم وثاني أكسيد الكربون استنادا إلى المعادلة التالية:

$$CaCO_{3(s)} + heat \rightleftharpoons CaO_{(s)} + CO2_{(g)}$$

بعد أن يصل النظام إلى حالة الاتزان الكيميائي في وعاء مغلق، ماذا سيحدث لتركيز CO_2 بعد إضافة المزيد من $CaCO_3$ إلى خليط الاتزان؟

(a) يزيد.

(b) يقل.

(c) لن يتغير.

السبب:

(1) زيادة كمية $CaCO_3$ في حالة الاتزان يسبب إنتاج اكثر للأيونات المذابة

(2) لأن إضافة $CaCO_3$ في جهة المتفاعلات، سيتجه التفاعل إلى جهة النواتج

(3) لأن إضافة $CaCO_3$ في جهة المتفاعلات، سيتجه التفاعل إلى جهة المتفاعلات

(4) تراكيز المواد الصلبة -أي أن كمياتهم في حجم وكثافة معينة- تبقى ثابتة

شكرا لك على وقتك ☺

Appendix B: Approvals

B.1 Abu Dhabi Department of Education and Knowledge (ADEK)

مجلس أبوظبي للتعليم
Abu Dhabi Education Council
Education First التعليم أولاً

التاريخ :- 18/ 5 /2017

السادة / مديري المدارس المعنية ... المحترمين

السلام عليكم ورحمة الله وبركاته ..

م/ تسهيل مهمة الباحثة في برنامج ماجستير.

يهديكم مكتب المدارس الخاصة أطيب التحيات ويشكر اهتمامكم وتعاونكم ...

ويسرنا أن نحيطكم علما بانه لا مانع لدينا من تسهيل مهمة الباحثة:- شهد يحيى كيالي - جامعة الامارات العربية المتحدة - التخصص : مناهج وطرق التدريس مسجلة في برنامج الماجستير وتقوم بإعداد بحث من ضمن متطلبات برنامج الماجستير من خلال اجراء بحث بين طلبة المدارس التالية :-

- مدرسة براعم العين الخاصة - أكاديمية الاندلس الخاصة - توام النموذجية الخاصة .

يرجى التنسيق مع أدارات المدارس الخاصة بما ذكر اعلاه ...

وتفضلوا بقبول فائق الاحترام والتقدير

أ/ محمــد سيد الهاشمــي
مــدير مكتب المدارس الخاصة

مجلس أبوظبي للتعليم
المدارس الخاصة
Abu Dhabi Education Council
Private Schools

هيا المزروعي
البريد الالكتروني : haya.almazroui @adec.ac.ae
رقم هاتف المكتب : 03/7078054

صندوق بريد:٣٦٠٠٥، أبوظبي - أ.ع.م، هاتف: ٠٠٠٠ ٦١٥ ٢ ٩٧١+، فاكس: ٠٥٠٠ ٦١٥ ٢ ٩٧١+، البريد الإلكتروني: info@adec.ac.ae
P.O.Box: 36005, Abu Dhabi - UAE, Tel: +971 2 615 0000, Fax: +971 2 615 0500, Email: info@adec.ac.ae

B.2 UAE University Approval

UAEU College of Education

جامعة الإمارات العربيـة المتحدة
United Arab Emirates University

التاريخ: 2017/1/8

لمن يهمه الأمر

نود إفادتكم علماً بأن الطالبة: شهد يحيى كيالي

الرقم الجامعى : 200834970

التخصص : مناهج وطرق التدريس

مسجله في برنامج الماجستير وتقوم بإعداد بحث بعنوان:

INVESTIGATION OF HIGH SCHOOL SCIENCE STUDENTS' MISCONCEPTIONS OF CHEMICAL EQUILIBRIUM

من ضمن متطلبات برنامج الماجستير. لذا نرجو التكرم بالموافقة على تسهيل مهمتها البحثية.

شاكرين ومقدرين حسن تعاونكم.

هذا وتفضلوا بقبول فائق التحية والتقدير.

منسق برنامج الماجستير

د. هالة الحويرص

College of Education
Assistant Dean for Research and Graduate Studies
PO BOX 15551, Al Ain, UAE
T +971 3 713 6221 T +971 3 713 6249
www.cedu.uaeu.ac.ae/graduateprogram/

كلية التربية
مساعد العميد لشؤون البحث العلمي والدراسات العليا
ص.ب 15551، العين، الإمارات العربية المتحدة
+971 3 713 6249 ت + 971 3 713 6260 ت
www.cedu.uaeu.ac.ae/graduateprogram/

B.3 Schools' Approvals

BARAEM AL AIN SCHOOL
Al Ain, Abu Dhabi
Near Sheikh Khalid Palace
Tel.: 7678848 - Fax : 7678847- P.O.Box: 80417

مدارس بـراعـــم العـــين
العين – أبوظبي
جـنوب قصر الشيخ خالد
تلفون : ٧٦٧٨٨٤٨ – فاكس : ٧٦٧٨٨٤٨ – ص.ب : ٨٠٤١٧

E-mail : Baraem77@yahoo.com

Date :02/05/2017......:التاريخ

السيد الفاضل / مدير مجلس أبو ظبي للتعليم المحترم ،،،

عناية الأستاذ/ هيا المزروعي ، مدير قسم الأنشطة المحترم ،،،

تحية طيبة وبعد

نحيط علم سيادتكم بأنه لامانع لدينا من السماح للأستاذة / شهد يحي كيالي

من مساعدتها في البحث الذي تقوم به (مناهج طرق التدريس) وإستضافتها خلال فترة عمل البحث

لدى المدرسة ، على أن تنتهي من إجراء البحث بنهاية هذا العام 2017/2016م .

وتفضلوا بقبول فائق الإحترام

مدير المدرسة ،،،

د /

مدارس براعم العين الخاصة
العين

TAWAM PRIVATE MODEL SCHOOL مدرسة توام النموذجية الخاصة

اليوم : الخميس.
التاريخ : 2017/05/04.

لمن يهمه الأمر

لا مانع لدى إدارة المدرسة من أن تكون ضمن العينة المشاركة في الدراسة البحثية الخاصة بالباحثة : (شهد يحيى كيالي) تسهيلاً لمهمتها البحثية في تخصص مناهج وطرق تدريس.

هذا للتكرم بالعلم.

وتفضلوا بقبول فائق الاحترام والتقدير.

مدير المدرسة.

مدرسة توام النموذجية الخاصة
TAWAM PRIVATE MODEL SCHOOL

هاتف: 03-7810912 - فاكس: 03-7810902 - ص.ب: 24925 - فلج هزاع - العين - ا.ع.م.
Tel: 03-7810912 - Fax: 03-7810902 - P.O. Box: 24925 - Falaj Haza'a - Al Ain - U.A.E.

عضو في المجلس العربي للموهوبين والمتفوقين
عضو في الشبكة العالمية للمدارس المنتسبة باليونسكو

Al Andalus Private Academy
أكاديمية الأندلس الخاصة

الإمارات العربية المتحدة
مجلس أبوظبي للتعليم
مكتب العين
أكاديمية الأندلس الخاصة

التاريخ : 2017/5/4 م
8/ شعبان 1438 هـ

السادة مجلس أبو ظبي للتعليم – مكتب العين المحترمين

تحية طيبة وبعد

الموضوع : لامانع

لامانع لدى إدارة أكاديمية الأندلس الخاصة من تسهيل مهمة الباحثة:

شهد يحي كيالي في تخصص المناهج وطرق التدريس في حال أتيح لنا الوقت المناسب لذلك وبما فيه مصلحة الطلبة .

مدير الأكاديمية
يحي نايل الضمور

أكاديمية الأندلس الخاصة
P.O.Box: 90735
Al Ain - U.A.E
Al Andalus Private Academy