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FRESHMAN STUDENTS' MISCONCEPTIONS IN CHEMICAL EQUILIBRIUM

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ÖZET: Bu çalışmanın amacı üniversite birinci sınıf öğrencilerinin kimyasal denge konusundaki kavram yanılgılarını belirlemektir. Bu çalışmıa, 143 Biyoloji, Biyoloji Öğretmenliği, Fizik ve Fizik Öğretmenliği Bölümü öğrencilerinin katılımıyla 1998-1999 bahar döneminde ODTÜ' de gerçekleştirilmiştir. Kimyasal Denge Kavramları Başarı Testi tüm öğrencilere uygulanmıştır. Sonuçlar, bir çok öğrencinin denge şartlarının değişmesi, tepkime hızı ile denge arasındaki ilişki ve tepkime hızı ve tepkime kavramı hakkında kavram yanılgısı olduğunu göstermiştir.

ANAHTAR SÖZCÜKLER: *Kavram Yanılgısı, Kimyasal Denge, Kimya Eğitimi.*

ABSTRACT: The purpose of this study was to investigate the misconceptions of freshman students in chemical equilibrium. In this study, 143 freshman students from Biology, Biology Education, Physics and Physics Education Departments in METU took part during 1998-1999 spring semester. Chemical Equilibrium Concepts Achievement Test was administered to all subjects. The results showed that many students had misconceptions about changing equilibrium conditions, relating rate and equilibrium and rate vs. extent.

KEY WORDS: *Misconception, Chemical Equilibrium, Chemistry Education*

1. INTRODUCTION

The purpose of this study was to investigate the misconceptions of Freshman students from Biology, Biology Education, Physics and Physics Education Departments in METU in chemical equilibrium.

Many students at all levels struggle to learn chemistry, but are often unsuccessful. One possible answer is that many students do not construct appropriate understandings fundamental chemical concepts from the very beginning of their studies (1). Therefore, they cannot fully understand the more advanced concepts that build upon the fundamentals.

Researchers have documented the fact that students often have naive ideas about how the world works, which hinder the learning of scientific explanations (2,3). It is clear that students use preexisting conceptions constructed from reflection on previous experiences to reason about newly presented science concepts, and to make sense of their instructional science experiences (4,5) Such preconceptions are often incorrect from a scientific viewpoint and can interfere with students' learning of science (4,6,7). Some student misconceptions are very resistant to instructional change and some students persist in giving answers consistent with their misconceptions even after large amounts of instruction (4,8,9,10,11,12). What a student learns, therefore, results from the interaction between what is brought to the learning situation and what is experienced while in it (13).

A review of literature reveals that there are four topics within the domain of chemistry that give learners most difficulty: chemical equilibrium, the mole, reaction stoichiometry and oxidation-reduction (14). Of these, chemical equilibrium concept is regarded as the most difficult concept for students to comprehend (15). Because the topics are very abstract and some words from everyday language are used with different meanings.

Children go through four stages of intellec-

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tual development starting at the sensory-motor phase, through the preoperational and concrete operational stages, to the formal operational phase when abstract thinking becomes possible (16). Although Piaget claimed that the formal operational phase would be attained at the age of 13 to 17 years, the rate at which children pass through the four phases varies. Thus, many students may not be able to deal with the cognitive transformations associated with abstract reasoning and may still require concrete example before concepts can be grasped (17).

The concept of "chemical equilibrium" includes a label that is known to students attending chemistry classes and for which they have a preconception. This preconception stems from the label "equilibrium" being used in physics as well as in some everyday life balancing situations such as circus acrobatics, bicycle riding, or weighing balance. The label "equilibrium" acquires attributes that are characteristic of these situations. Attributes of equality in general, equality of two sides, stability, and a static nature become associated with the concept of equilibrium (18). However, these attributes of equilibrium are the very ones that actually differentiate between physical and chemical equilibrium. Phenomena that reach chemical equilibrium appear naturally macroscopically as stable and static systems. On the other hand, on the microscopic level the system is dynamic not only because of molecular movement but also because the process of breaking and creating bonds go on with the net result of zero. Attributing macroscopic qualities to the microscopic level leads to misconceptions in the understanding of the concept 'chemical equilibrium". (19)

Bergquist and Heikkinen (1990) have pointed out that equilibrium is fundamental to the understanding of acid- base behavior, oxidation-reduction reactions and solubility. (20) Mastery of the concepts associated with equilibrium facilitates mastery of the other chemical concepts.

The following is the table of misconceptions of students in chemical equilibrium which is derived from review of related literature:

I. Approach To Equilibrium

a) The rate of forward reaction increases with time from mixing reactants until equilibrium is established

b) Reverse reaction rate is the same as the forward rate

II. Characteristics of Chemical Equilibrium

a) There is a simple arithmetic relationship between the concentrations of reactants and products such as [reactants]=[products] at equilibrium

b) Forward reaction must be completed before reverse reaction starts

c) Lack of awareness to the dynamic nature of the chemically equilibrated state, equilibrium is seen as the firmly held concept of a static two-sided picture

d) Concentrations fluctuate as equilibrium is established

IV. Changing Equilibrium Conditions

i. Effect on concentrations

a) Addition of more reactant changes only the product concentrations

b) Uncertainty how a temperature, volume or pressure change will alter the equilibrium concentrations

ii. Relating Rate and Equilibrium

If a system at equilibrium is disturbed by some change, the system will shift so as to partially counteract the effect of change. The rate of the reaction to which the equilibrium shifts will be greater when a new equilibrium is established.

iii. Effect on equilibrium constant

a) Equilibrium constant varies in value while at constant temperature

b) When the temperature is increased and equilibrium is re-established the equilibrium constant is the same as under the initial conditions

c) Value of equilibrium constant changes with amounts of products or reactants

d) Value of equilibrium constant changes with volume

e) Value of equilibrium constant changes with pressure

f) Value of equilibrium constant increases if a catalyst is used

iv. Effect of a catalyst

a) A catalyst can affect the rates of forward and reverse reactions differently

b) A catalyst leads to a higher yield of product

V. Reversibility vs. Completion

A reaction is reversible yet goes to completion that is no discrimination between reactions that goes to completion and reversible reactions

VI. Rate vs. Extent

Failure to distinguish between rate (how fast) and extent (how far) of reaction

VII. Mass vs. Concentration

a) Uncertainty when to use volume

b) Confusion regarding amount (moles) and concentration (molarity)

4. METHOD

2.1 Subjects

In this study, 143 freshman students taking General Chemistry course (Chem 102) in 1998-1999 spring semester took part. Chem-102 course includes chemical equilibrium chapter. After students covered this chapter, Chemical Equilibrium Concepts Achievement Test was administered. The distribution of students according to departments is as follows:

Table 1. Distribution of subjects with respect to departments

Department	Count
Biology	30
Biology Education	30
Physics	38
Physics Education	45

2.2 Instruments

In this study, Chemical Equilibrium Concepts Achievement Test was administered to all subjects. This test was developed by Geban and Özdemir. It consisted of 25 multiple choice questions. Both English and Turkish versions of the test were given to students at the same page because some students have taken chemistry course in Turkish in high school. During the development stage of the test, firstly, the instructional objectives were determined. Secondly, the literature related to students' misconceptions with respect to chemical equilibrium was carefully examined. Each distracter of an item was prepared in such a way that it was confronted with students' misconceptions. The items were evaluated by a group of classroom teachers and experts in science education and chemistry for the appropriateness of the items and the content validation. The reliability of the test was found to be 0.80.

Some items from the Chemical Equilibrium Concepts Achievement Test:

Consider an equilibrium mixture:

$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g) + heat$ at 200°C and 1 atm pressure.

Indicate the new situation in each of the items by marking the appropriate letter on the right side of the sentences by using the following key:

A: greater than that in the initial equilibrium;

B: less than that in the initial equilibrium;

C: same as that in the initial equilibrium;

D: data insufficient for conclusion

1. Some Cl_2 is removed from the system, the volume and the temperature being kept

constant. When the system returns to another equilibrium,

(a) The rate at which NO is being formed will be .....

(b) The concentration of NOCl present will

be .....

(c) The equilibrium constant will be .....

2. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ + heat reaction is at equilibrium. Which one of the following increases the concentration of CO_2 gas?

A) Decreasing the concentration of CO gas

B) Decreasing the concentration of O_2 gas

C) Using a catalyst

D) Increasing the temperature

E) Increasing the pressure

3. For the reaction $A_2(g) + 2B_2(g)$ $2C(g)$ which one of the following is true?

I. At equilibrium, $[A_2] =$ $=$

II. At equilibrium the rate of forward and reverse reactions are equal to zero

III. At equilibrium the concentrations of gases are constant

A) Only I B) Only II C) Only III

D) I and II E) I, II and III

4. Consider the following equilibrium system:

$N_2(g) + 3H_2(g)$ $2NH_3(g)$

Suppose 1 mole of each of three gases are mixed and allowed to reach equilibrium by the conversion of "x" moles of NH_3 gas into H_2 and N_2 gases in a 2 liters container. What is the molar concentration of N_2 at equilibrium?

A) 0.5+0.25x B) 1+0.5x C) 0.5+0.5x

D) 1+0.25x E) 1+x

3. RESULTS

Statistical analyses were carried out by SPSS, Statistical Package for Social Sciences for Personal Computers. Students' correct proportions to questions were calculated.

By giving 1 point for each question and sub-question, students' total scores were found. The scores varied from 7 to 31 out of 35. The mean of total scores was found to be 22,41.

For the question related to changing equilibrium conditions the correct proportion was found to be 0,19. Students think that a catalyst leads to higher yield of product. Students have uncertainty how a temperature, volume or pressure change will alter the equilibrium concentrations.

Only 40% of the students answered correctly to the questions in which they were asked to find the equilibrium concentration of species. In order to solve these questions, they had to convert given moles to molarities. But many of the students confused the amount (moles) and concentration (molarity).

Moreover, students had difficulty in relating rate and equilibrium. They think that if a system at equilibrium is disturbed by some change, the system will shift so as to partially counter act the effect of change and the rate of the reaction to which the equilibrium shifts will be greater when a new equilibrium is established. The correct proportions for these questions were found to be 0,60, 0,45 and 0,50 respectively.

In addition, 80% of the students failed to distinguish between rate (how fast) and extent (how far) of reaction.

4. DISCUSSION

The purpose of this study was to investigate the misconceptions of Freshman students from Biology, Biology Education, Physics and Physics Education Departments in METU in chemical equilibrium.

Generally, students solve problems successfully using memorized algorithms. Many students who may be successful at solving mathematical problems do not understand the chemical concepts behind their memorized algorithmic solutions.

Many students exhibit misconceptions in several content areas in chemistry. One of these areas is the chemical equilibrium since firstly, the concepts are seen abstract and secondly, the words from everyday language are used but with different meanings. Statements of equilibrium concepts contain everyday terms such as shift, equal, stress and balanced. Such vocabulary can lead to very different visual images. For this reason, the different attributes of equilibrium and chemical equilibrium must be analyzed and presented to overcome the confusion of these concepts.

Some misconceptions regarding chemical equilibrium might be the result of instruction that emphasis correct concepts without highlighting common conceptual errors. Chemistry teachers should be aware of students' the prior knowledge and misconceptions. They should examine why misconceptions occur and use learning activities to eliminate misconceptions. Because, it is very difficult to remove misconceptions from the minds of the learners.

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