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High School Students' Conceptions about Energy in Chemical Reactions

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Öz

Bu çalışmanın amacı öğrencilerin ısı ve sıcaklık, endotermik-ekzotermik tepkimeler, yanma tepkimeleri, bağ enerjisi, entalpi, kimyasal tepkimelerde kararlılık ve kalorimetre konularını kapsayan kimyasal tepkimelerde enerji ünitesiyle ilgili kavram yanılgılarını araştırmaktır.Örneklem 222, 10.sınıf öğrencisinden oluşmaktadır. Bu çalışmada hem nitel hem de nicel yöntembilim kullanılmıştır. Öğrencilerin konuyla ilgili kavramalarını ölçmek için her biri 5 seçenekli olmak üzere 20 sorudan oluşan çoktan seçmeli bir test geliştirilmiştir. Bu kavram testi öğrencilerin literatürde kimyasal tepkimelerde enerji konusuyla ilgili kavram yanılgıları ve öğrenme zorlukları göz önünde bulunarak geliştirilmiştir. Ek olarak, öğrencilerin konuyu anlamalarıyla ilgili daha derin bilgi elde etmek amacıyla yarı yapılandırılmış mülakatlar yapılmıştır. Sonuçlar göstermiştir ki kimyasal tepkimelerde enerji konusu, pek çok bölümünde öğrencilerin zorlandığı ve birçok kavram yanılgısına sahip olduğu bir ünitedir. Bulunan bazı kavram yanılgıları literatürdeki bulgularla benzerlik gösterirken, bazıları da çelişmektedir. Ayrıca, konuyla ilgili yeni kavram yanılgıları da tespit edilmiştir.

Anahtar Sözcükler: Kavram yanılgısı, kimyasal tepkimelerde enerji.

Lise Öğrencilerinin Kimyasal Tepkimelerde Enerji Konusundaki Kavramaları

Abstract

The aim of this study is to investigate students' understanding of the energy concept in chemical reactions including heat and temperature, endothermic-exothermic reactions, combustion reactions, bond energy, enthalpy, stability in chemical reactions and calorimeter. The sample consisted of 222, 10^{th} grade students. Both qualitative and quantitative methodology was used for this investigation. A twenty-item multiple choice test was developed about the topic to measure the students' understandings. This concept test was prepared based on students' conceptual difficulties and misconceptions related to the energy in chemical reactions found in the literature. In addition, semi structured interviews were conducted to get deep knowledge about students' perceptions. Results showed that for most parts, energy in chemical reactions is a difficult topic for high school students and they had various misconceptions. While some of the misconceptions were parallel to the literature findings, some of them contradicted with it. Also, some novel misconceptions were detected.

Keywords: Misconception, energy in chemical reactions.

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Introduction

Students may develop some conceptions, different from the scientifically accepted view, based on their daily life experiences, teachers' instruction, and textbooks. These conceptions are called misconceptions, which influence students' learning negatively. Therefore, it is important to identify these conceptions and develop teaching strategies to overcome them (Driver, Squires, Rushworth, & Wood-Robinson, 1994; Gilbert, Osborne & Fensham, 1982). Research studies showed that students, even at university level, were found to have misconceptions about energy in chemical reactions (Barker & Millar, 2000; Boo, 1998; BouJaoude, 1991; De Vos & Verdonk, 1986; Greenbowe & Meltzer, 2003; Johnstone, MacDonald & Webb, 1977; Niaz, 2000; Paik, Cho & Go, 2007). The purpose of this study is to find out Turkish high school students' conceptions about energy in chemical reactions. Literature related to students' misconceptions about energy in chemical reactions was reviewed under five major headings; *heat and temperature, endothermic and exothermic reactions, combustion reactions, bond energy,* and *calorimeter*.

Several research studies revealed some common misconceptions of students about heat and temperature. It was found that many students couldn't distinguish between heat and temperature (Erickson, 1979; Erickson, 1980; Harrison, Grayson & Treagust, 1999; Kesidou & Duit, 1993; Niaz, 2000; Niaz, 2006; Paik et.al., 2007; Yeo & Zadnik, 2001). In addition, some studies showed that most students thought heat as a substance rather than energy whereas they described temperature as intensity of heat. Similarly, most students were found to think that temperature of objects can be determined by skin and materials like wool have the ability to warm things (Yeo & Zadnik, 2001).

Research studies illustrated that students had difficulties in identifying chemical reactions as endothermic or exothermic. For example, students thought burning of candle as an endothermic reaction since heat was needed to initiate the reaction. They also classified burning of copper as an endothermic reaction since only heating of copper caused formation of copper oxide (Boo, 1998; De Vos & Verdonk, 1986). Studies of Thomas and Schwenz (1999) and Johnstone et.al., (1977) stated that students had a misconception that endothermic reactions cannot be spontaneous. In addition, students thought that all reactions occurring naturally without application of heat are exothermic (Johnstone et.al., 1977).

Bond energy is another concept about which students were found to have misconceptions. In terms of overall energy change, Boo (1998) reported that 12th grade students in his research considered bond breaking as an energy release process whereas they thought that energy is required for bond making. Similarly, the notion that both processes of bond breaking and bond making require input of energy was common among 12th grade students. Barker and Millar (2000) also confirmed students' misconceptions about bond energy since they found that half of the students considered bond making as endothermic even after science instruction.

In terms of combustion concept, BouJaoude (1991) detected several misconceptions. For example, some students thought that combustion always involves fire or flame. In addition, students' explanations about combustion were inconsistent, for example, they considered burning of alcohol as evaporation, however, burning of wood as change into ashes.

Recently, Greenbowe and Meltzer (2003) investigated students' conceptions about energy in chemical reactions in the context of calorimeter. This study showed that many students couldn't identify system and surrounding. Similarly, students couldn't use the equation, $q= m.c.\Delta t$ in a meaningful way since they couldn't understand the relationship between heat flow, specific heat, and temperature change. Cohen and Ben-Zvi (1982) also reported students' lack of understanding in using the equation, $q= m.c.\Delta t$.

As mentioned above, research studies indicated that students had some misconceptions in the context of energy in chemical reactions. In the light of these findings, research question for this study is:

- What are Turkish high school students' conceptions about energy in chemical reactions after instruction?

Methodology

Sampling

222 Turkish high school students from different high schools participated in this study. 103 of them were female whereas there were 119 male students. These were 10th grade students, who had already learnt energy in chemical reactions concept.

Data collection tools

In this study, two instruments were used; Energy in Chemical Reactions Concept Test (ECT) and semi-structured interviews, in order to collect data. Test items and the interviews were in Turkish.

ECT consisted of 20 multiple-choice questions. Each question had five alternatives. The test was designed according to misconceptions found in the literature (Boo, 1998; BouJaoude, 1991; Ceylan, 2004; Cohen & Ben-Zvi, 1982; De Vos & Verdonk, 1986; Kesidou & Duit, 1993; Thomas & Schwenz, 1999; Yeo & Zadnik, 2001). In addition, interviews with chemistry teachers helped us determine possible difficulties of students during the instruction of this topic. Therefore, misconceptions in the literature as well as students' difficulties determined the distracters of this test. The test measured students' understanding of different concepts about energy in chemical reactions; *heat and temperature, exothermic and endothermic reactions, bond energy, combustion reactions, enthalpy,* and *calorimeter*. Two of the questions about heat and temperature were adapted from the study of Niaz (2000). On the other hand, five questions related to enthalpy, combustion reactions and calorimeter concepts were adapted from Ceylan (2004).

For the content validity of the test, five chemistry teachers and one chemistry educator evaluated the appropriateness of test items. The test was administered to all participants at once. The Cronbach alpha value was found as 0.70 indicating adequate reliability.

ECT was applied to 222 10th grade high school students. Based on the frequencies of students' responses, seven students were interviewed. Semi-structured interviews were used to supplement the analysis of test results. The interviews were carried out with seven students, who completed the test. The purpose of the interviews was to obtain deeper information about students' reasoning in energy in chemical reactions concepts. To select interviewees, firstly, frequencies of students' responses for each question in the test were determined. Based on frequency analysis, students with different misconceptions were selected. Before the interviews, a semi-structured interview schedule was prepared considering students' responses in the test. Each interview lasted about 30 minutes. They were all audio-taped and transcribed.

Data Analysis

For the data analysis, SPSS 11.5 was used to determine the reliability of the concept test and frequencies of students' responses to each alternative. Moreover, semi-structured interviews were conducted and transcribed by the researchers to obtain more information about students' understandings.

Findings

Descriptive statistics was used to find out frequencies of students' responses for each question in the multiple choice test. Table I shows percentage of students' responses for alternatives of each question in ECT. Results are reported under five sections, *heat and temperature, exothermic and endothermic reactions, bond energy, combustion reactions, enthalpy* and *calorimeter*.

Heat and Temperature

Three questions (2, 9, 20) were asked to assess students' understanding of heat and temperature concepts. It was found that about 30% of the students had the misconception that temperature could be transferred from one object to another (Question 2). Interviews with some of these students also indicated that they couldn't differentiate between heat and temperature. They tried to explain the difference with the help of the formula, $Q = m.c.\Delta t$, and the units "kkal" and "°C". However, they couldn't define these terms and their differences.

Table 1. Percentage of students' responses to alternatives of each question

Questions	Alternatives				
	A	B	C	D	E
1	76.9	11.3	2.7	4.5	4.5
2	14.4	7.0	52.6	21.4	4.7
3	3.2	5.0	16.2	0.5	75.2
4	7.1	1.9	20.0	21.0	50.0
5	6.1	48.1	6.6	35.8	3.3
6	1.9	19.2	33.8	2.8	42.3
7	31.4	8.6	23.8	9.5	26.7
8	55.7	3.3	2.8	5.2	33.0
9	7.5	76.1	5.2	3.8	7.5
10	4.6	7.9	70.4	4.6	12.5
11	82.4	1.8	1.8	5.0	9.0
12	2.3	23.2	2.3	62.3	10.0
13	1.8	11.8	78.2	5.0	3.2
14	62.2	11.1	6.0	17.5	3.2
15	8.5	80.2	3.3	2.4	5.7
16	6.6	44.7	8.1	23.4	17.3
17	14.4	3.8	26.0	9.1	46.6
18	2.4	7.1	10.5	79.0	1.0
19	0.9	25.9	16.5	41.5	15.1
20	23.0	67.9	5.3	2.4	1.4

R (Researcher): What is the difference between heat and temperature?

S (Student): The units of heat and temperature are Calorie and Degree Centigrade respectively.

R: Yes. You are right. Then, what is the difference between them?

S: The formula; $Q = m.c.\Delta t$, gives us heat.

R: Can you define heat?

S: No, I can't. I can only give you this formula.

R: Can temperature pass through one substance to another?

S**:** Yes. When we make a hot iron touch to a cold one, temperature flows from hot to cold.

76% of students gave correct response when asked the reason for feeling cold when we touch the bottle of milk taken from a refrigerator compared to the milk at room temperature (Question 9). In addition, most students (68 %) didn't have any problems in understanding the relationship between mass of an object and the heat emitted when asked to compare the heat taken by two containers with different amount of water being heated by the same heaters at the same conditions until being boiled. On the other hand, 23% of students reflected that they take the same amount of heat regardless of their masses because mass only affects time passing until boiling (Question 20).

Exothermic and Endothermic Reactions

Four questions (1, 3, 7, 19) were related to exothermic and endothermic reactions. Analysis of responses for question 1 one of the related questions revealed that 76, 9 % of students didn't have any difficulties in identifying burning of candle, copper and darkening of silver as exothermic reactions. However, about 60% of students considered all reactions occurring spontaneously as exothermic. In addition, approximately 30% of the students thought that heat was always needed for chemical reactions to occur (Question 7). They couldn't imagine the possibility of chemical reactions to be spontaneous.

Analysis of multiple choice responses yielded another common misconception about exothermic and endothermic reactions, which is the stability concept. In the interview, it was understood that some students associated stability with power:

> R: Are products more stable in exothermic reactions at lower temperatures?
>
> S: Yes, heat is in the product side in exothermic reactions so it is correct.
>
> R: Why did you say that product side is the more stable side? Did you learn like that?
>
> S: It is more reasonable, isn't it? Since, there is something to protect the products, which is the heat.
>
> R: But why is it stable?
>
> S: Since, it is powerful due to heat. This makes it stable.

These students thought that heat makes something more powerful, thereby more stable. They believed that if heat is on the products' side, it makes the products more powerful and vice versa. So if a reaction is exothermic, products are more stable than reactants because they have more power due to heat. In addition, during the interview, some students associated stability in endothermic and exothermic reactions with inert gases without any further explanations.

Bond Energy

Three items (4, 11 and 13) were about the classification of bond breaking and formation reactions as exothermic and endothermic. It was found that students had some misconceptions about energy change of bond breaking and bond formation processes. Related dialogues are given below:

> R: Is bond formation an endothermic or exothermic reaction?
>
> S**:** Endothermic because bond formation process cannot occur spontaneously; we should intervene or give heat to form a bond.
>
> R: What about the bond breaking?
>
> S**:** It is exothermic.
>
> R: Can you explain us why it is exothermic?
>
> S**:** Atoms preserve energy inside them, when we break a bond, this energy is released.

Students generally have a misconception that bond formation is endothermic and bond breaking is exothermic. They believed that to form something, we must make an effort and so energy should be used up. In addition, because atoms keep energy in themselves, during bond breaking process, energy comes out.

In the multiple choice test, bond energy concept was measured both verbally and visually. When the question was verbally stated, about half of the students said that bond breaking releases energy; bond formation requires energy consumption. Conversely, when the question involved only bond breaking and formation equations, e.g. $H + H \rightarrow H_2$, without giving any explanation about the kind of reaction as bond breaking and formation, most of the students gave the correct response to these questions (Questions 11 and 13). This may be because of the fact that students are used to solving multiple choice questions where chemical reactions are given.

Combustion Reactions

Two questions (8, 12) were asked in order to obtain students' understanding of the combustion. In question 8, one of the questions, some enthalpy change values of equations for combustion reactions were given and students were asked to find out the best fuel considering equal masses of each. 45% of the students couldn't answer this question correctly. When asked to expand their reasons for their choice during the interview, some of the students preferred the one with the highest combustion enthalpy while deciding the best fuel:

> R: Why did you choose C_2H_6 for the answer of question 8?
>
> S**:** All of them are exothermic but C_2H_6 has more ΔH with respect to others.

However, some students decided the best fuel by looking only at molecular weight of fuels:

> R: Did you consider equal amounts of each?

S: No, I didn't.

R: Now, if you consider equal amounts of each fuel, which one do you choose?

S: I take the one with the biggest molecular weight.

R: Why? Do you think the more molecular weighted one gives more heat?

S: Yes, it does.

As understood from the above transcripts, most students had difficulties in deciding the best fuel by both considering enthalpy change and equal amounts of each. On the other hand, test results showed that most students didn't have any problems to understand that combustion reactions didn't always involve fire or flame. However, some students thought that all combustion reactions always occur spontaneously (Question 12). In the interview, they explained that all combustion reactions are exothermic and all exothermic reactions are spontaneous. During the interview, it was understood that some students always expected to see CO_2 gas and H_2O as products in a combustion reaction.

Calorimeter

Four questions (14, 16, 17, 18) were about the calorimeter concept. Most students appeared to understand that exothermic reactions would cause an increase in temperature whereas endothermic reactions would cause a decrease in it in the calorimeter (Questions 14, 18). However, interviews with these students showed that they didn't know calorimeter system; how it looks like and works. Therefore, since these students didn't actually know how reactions occur inside a calorimeter, they just memorized that exothermic reactions would cause an increase whereas endothermic reactions would cause a decrease in temperature as a rule. For example, one of the students gave the following explanations in the interview:

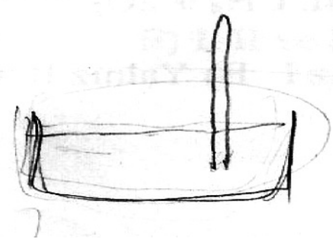
R: Can you draw a calorimeter?

S: Yes. (He drew the figure below

R: Where does the reaction occur?

S: In the water.

R: How can we decide that a reaction isexothermic or endothermic in the calorimeter?



S: If temperature of water increases, reaction is exothermic. Heat is given directly to the water.

According to this student, reaction occurs in water. The above explanations indicate the lack of conceptual understanding of students about the calorimeter. One of the reason might be that calorimeter concept is not emphasized conceptually in chemistry lessons. Only some of problems related to calorimeter are solved. Similarly, most students could not identify system and surrounding in the context of calorimeter (Question 16). They just tried to guess that surrounding is outside of the calorimeter and system is everything inside the calorimeter.

Enthalpy

Questions related to enthalpy assessed students' conceptions of enthalpy of formation, Hess Law and molar enthalpy of combustion (Questions 5, 6, 10, 15). Analysis of students' responses showed that many students didn't have a sound understanding of enthalpy of formation (Question 5) though they didn't have any problems with the enthalpy of combustion (Questions 10,15). Interviews showed that they didn't know the meaning of enthalpy of formation.

R: What is enthalpy of formation?

S: It is the minimum energy to form a product.

R: In the below reactions, which of the energy change is the enthalpy of formation? And why?

$$C_{(s)} + 1/2O_{2(g)} \longrightarrow CO_{2(g)} + \text{heat}$$

$$CaO_{(s)} + 1/2O_{2(g)} \longrightarrow CaCO_{3(s)} + \text{heat}$$

S: Both of them. Because, in both reactions, something forms.

Like the above student, some students thought that if something is formed in a reaction, ΔH of that reaction equals to enthalpy of formation. Students believe that enthalpy of formation and ΔH are always the same thing. Moreover, as seen in the dialogue above, this student could not distinguish between enthalpy and activation energy.

Besides, some students had difficulty in understanding that enthalpy of a reaction depends on the phases of the reactants and products. For example,

$$H_{2(g)} + 1/2O_{2(g)} \longrightarrow H_2O_{(g)}$$

$$H_{2(g)} + 1/2O_{2(g)} \longrightarrow H_2O_{(l)}$$

These students said that ΔH's of both reactions are equal though these values are different.

Interviews with students denoted that some of the students relate the sign of ΔH to the amount of products compared to reactants:

R: What did you understand from "+" and "-" value of ΔH?

S**:** ΔH = Product – Reactive. So, if it is "+", $\Sigma\Delta H_p > \Sigma\Delta H_r$. I mean we obtain more products.

R: Do we get more products when $\Delta H_p > \Delta H_r$?

S: Yes.

So this student believes that if ΔH is positive (+), the amount of products is bigger than that of reactants. This indicates that he didn't understand the concept of ΔH. He considered ΔH as change in the amount of products and reactants not as energy change.

Discussion

This study aimed to determine Turkish high school students' conceptions of energy in chemical reactions. It was found that most students in this study could not distinguish between heat and temperature. Although they knew that they are different, they could not define these terms and their differences. Specifically, common misconceptions about heat and temperature found in this study are listed below:

- Temperature can flow from an object to another.
- There is no relationship between mass and heat given or taken.

Studies of Niaz (2000) and Yeo and Zadnik (2001) also confirmed the above misconceptions.

This studyV also revealed that most students believed that all exothermic reactions are spontaneous. On the other hand, some students concluded that if all exothermic reactions are spontaneous, endothermic reactions will not be spontaneous. Also these students could not give examples to spontaneous-endothermic reactions. One of the reasons for this misconception may be the lack of the number of spontaneous - endothermic reactions compared to the spontaneous – exothermic reactions. In addition, some students could not imagine the possibility of formation of chemical reactions spontaneously; they thought that heat or any other agent was always necessary in order to initiate chemical reactions to occur. These misconceptions were also found in the studies of Thomas and Schwenz (1999) and Johnstone et.al., (1977).

Another common misconception, which is not encountered in the related literature, is the stability concept. Some of the students associated stability with power. They thought that if a reaction is exothermic, the products are more stable than the reactants because they have more power due to heat released. Moreover, during the interview, when asked to define the stability concept in endothermic and exothermic reactions, we faced that some students gave inert gases as an example of stable substances but they could not give any further explanations. One of the reasons for these thoughts may be that stability concept remained as a discrete knowledge in students' minds without linking it with the stability in exothermic and endothermic reactions.

Consistent with studies of Boo (1998) and Barker and Millar (2000), this study also indicated that students generally thought bond formation as endothermic and bond breaking as exothermic since they believed that some amount of energy must be used up to form something and stored energy in bonds is released during bond breaking process. Measuring bond energy concept both verbally and visually showed us more than half of the students gave incorrect answers when the statements about bond energy are given verbally whereas these students gave correct responses when the question involved visual elements, in which bond breaking and formation equations are seen clearly. One of the reasons may be that students are accustomed to solving problems in which bond breaking and formation equations are given directly. This shows that students could not learn this concept meaningfully.

On the other, this study showed some of the findings, which were inconsistent with the related literature. For example, in the present study, most of the students did not have any difficulties in identifying burning of candle, copper and darkening of silver as exothermic reactions. This finding contradicts with the study of De Vos and Verdonk (1986) who found that students in their study thought burning of candle as an endothermic reaction. This contradiction may be because of the fact that burning of candle was given as a common example of exothermic reactions in chemistry classes of Turkey.

Similarly, in terms of combustion reactions, as opposed to BouJaoude (1991), most students did not have any trouble in understanding that combustion reactions do not always involve fire or flame. However, some students considered the spontaneity of all combustion reactions. Another novel finding of this study is that CO2 gas and H2O are expected as products in a combustion reaction by some students. This may be because of the fact that in chemistry lessons, generally, combustion of hydrocarbons is given as a combustion reaction example.

As for the calorimeter concept, analysis of interviews showed that most students could not explain the principle behind the calorimeter. These students did not know the mechanism of a calorimeter so does energy exchange of a reaction in calorimeter. Additionally, identification of system and surrounding in the context of calorimeter is another problematic point.

Another aspect of the energy in chemical reactions scarcely mentioned in the literature is the enthalpy concept. This study added some new misconceptions to the literature related to enthalpy:

- Enthalpy of formation and ΔH are always the same thing.
- Enthalpy of a reaction does not depend on the phases of the reactants and products.
- If ΔH is positive (+), amount of products is bigger than that of reactants.

This study has some implications for chemistry instruction. Firstly, teachers should design teaching strategies according to students' misconceptions and their existing knowledge. For example, difference between heat and temperature can be emphasized by using concrete examples, demonstrations or analogies since it is among the topics that most of the students had difficulty in. In addition, lessons can be enriched by experiments related to spontaneous and non-spontaneous reactions. Calorimeter concept can be taught by using calorimeter demonstrations instead of drawing on board. Generally, students can be encouraged to construct their own knowledge by using teaching methods including conceptual change texts, demonstrations, cooperative group activities and simulations.

We believe that this study contributes to the chemistry education research since it revealed students' misconceptions about some aspects of the energy in chemical reactions topic such as enthalpy, stability in endothermic and exothermic reactions, which were not investigated in the literature. Bearing these misconceptions in mind, as a future study, effectiveness of different teaching strategies can be evaluated. Furthermore, the same study could be conducted with pre-service chemistry teachers in order to obtain their conceptions about energy in chemical reactions because the teachers are among the sources of misconceptions (Jacobs, 1989).

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Appendix: Sample Questions from ECT

2. I. Temperature can be transmitted from an object to another.

II. Heat absorption of an object that is heated depends on the mass of the object.

III. Energy written in reactants side is the activation energy.

IV. Total potential energy of reactants is greater than that of products in an exothermic reaction.

Which of the above statement(s) is/are true?

A) Only IV B) I and II C) II and IV

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

7- I. At constant temperature, heat given to the system increases potential energy of system.

II. Heat is always needed for a chemical reaction to occur.

III. All reactions occurring spontaneously are exothermic reactions

Which of the statement(s) above is/are <u>always true</u>?

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

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

8- Considering <u>equal amounts</u> of below fuels (H_2, CO, C, CH_4, C_2H_6), which one of the following is the best fuel? (H:1, C:12, O:16)

$H_2 + 1/2O_2 \rightarrow H_2O$ $\Delta H = -58$ kkal

$CO + 1/2O_2 \rightarrow CO_2$ $\Delta H = -68$ kkal

$C + O_2 \rightarrow CO_2$ $\Delta H = -94$ kkal

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $\Delta H = -210$ kkal

$C_2H_6 + 7/2O_2 \rightarrow 2CO_2 + 3H_2O$ $\Delta H = -340$ kkal

A) H_2 B) CO C) C

D) CH_4 E) C_2H_6

16. Imagine that a reaction occurs in a test tube in the laboratory.

I. The place where the reaction occurs is qualified as surrounding

II. Test tube is the boundary seperating the system from surrounding.

III. Laboratory is the system for the reaction.

Which of the statement(s) is/are true?

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

D) II and III E) I and II

Özet

Giriş: Enerji konusu biyoloji, fizik ve kimya bilim dallarını ilgilendiren önemli bir konudur. Literatürde lise seviyesinde, öğrencilerin kimyasal tepkimelerle ilgili olarak enerji konusunda genel hatlarıyla ısı-sıcaklık ve endotermik ekzotermik tepkimeler konularındaki kavramalarıyla ilgili çalışmalar vardır. Fakat, enerji kavramıyla ilgili olarak entalpi, kalorimetre ve kimyasal tepkimelerde kararlılık gibi önemli konularda çalışma yoktur. Bu çalışmanın amacı 10.sınıf öğrencilerinin kimyasal tepkimelerde enerji konusunu bir bütün olarak ele alıp, konunun ısı-sıcaklık, endotermik ekzotermik tepkimeler, yanma tepkimeleri, bağ enerjisi ve *kalorimetre* gibi tüm alt başlıklarıyla ilgili kavram yanılgılarını tespit etmektir. Oluşmasında günlük hayat, kitaplar ve kimi zaman da öğretmenin rol aldığı ve çoğunlukla bilimsellikten uzak olan, değişmeye dirençli bu kavram yanılgıları, öğrencilerin yeni kavramları öğrenmelerini olumsuz bir şekilde etkiler. Öğrencilerin fen bilimleriyle tanışmalarının ilköğretim yıllarına dayandığı ve 10.sınıf seviyesine gelene kadar fen kavramlarını yapılandırdığı düşünüldüğünde, kavram yanılgılarını tespit etmek ve ortadan kaldırmak için yapılan çalışmalar oldukça önemlidir ve konuyla ilgili yapılacak diğer çalışmalara da ışık tutacaktır.

Yöntem: Örneklem Türkiye'deki çeşitli okullardan 222 (103 kız, 119 erkek), 10.sınıf öğrencilerinden oluşmaktadır. Çalışmaya katılan öğrencilerin tamamı kimyasal tepkimelerde enerji konusunu daha önceden öğrenmişlerdir. Bu çalışma için hem nitel hem de nicel yöntembilim kullanılmıştır. Öğrencilerin kimyasal tepkimelerde enerji konusuyla ilgili kavramalarını ölçmek için her biri 5 seçenekli olmak üzere 20 sorudan oluşan çoktan seçmeli bir test geliştirilmiştir. Bu test öğrencilerin literatürde kimyasal tepkimelerde enerji konusuyla ilgili kavram yanılgıları ve öğrenme zorlukları göz önünde bulunarak hazırlanmıştır. Testin içerik güvenilirliği 5 kimya öğretmeni ve 1 kimya eğitimci tarafından değerlendirilmiştir ve geçerlilik değeri (Cronbach alpha) 0.70 olarak bulunmuştur. Ek olarak, öğrencilerin konuyu anlamalarıyla ilgili daha derin bilgi elde edinmek amacıyla yarı yapılandırılmış mülakatlar yapılmıştır. Görüşme yapılacak öğrencileri seçmek için onların testteki her bir soruya verdikleri cevapların frekansı belirlenmiştir ve bu sonuçlara dayanarak içlerinden farklı kavram yanılgılarına sahip olanlar seçilmeye çalışılmıştır.

Bulgular:

Sonuçlar bazı kavram yanılgılarının literatürdeki bulgulara benzer olduğunu gösterirken, bazıları da onlarla çelişmektedir. Ek olarak, bazı yeni kavram yanılgıları tespit edilmiştir. Sonuçlara göre, öğrencilerin yaklaşık % 30'u "sıcaklık bir cisimden diğerine aktarılabilir" kavram yanılgısına sahip olduğu belirlenmiştir. Öğrencilerle yapılan mülakatlar da, onların ısı ve sıcaklığı birbirinden ayırt edemediğini göstermiştir. Çoğu öğrencinin (68 %) bir cismin kütlesi ile yaydığı ısı enerjisi arasındaki ilişkiyi anlaması konusunda bir problem olmadığı tespit edilmiştir. Ayrıca, öğrencilerin yaklaşık % 60'ı kendiliğinden gerçekleşen bütün tepkimeleri ekzotermik tepkime olarak düşünmüştür. Bunun yanı sıra, bu öğrenciler eğer bütün ekzotermik tepkimeler kendiliğinden oluyorsa, endotermik tepkimeler kendiliğinden gerçekleşemez yargısına sahiptirler ve dolayısıyla bu tepkimelere örnek de verememektedirler.

Mülakatta bazı öğrencilerin kararlılık ve güç kavramlarını arasında bağlantı kurduğu anlaşılmıştır. İlgili kavram yanılgısı ise "ısı bir şeyi daha güçlü yapar, böylece daha kararlı hale getirir". Dolayısıyla, öğrencilerin "eğer bir tepkime ekzotermik ise ürünler girenlerden daha kararlıdır çünkü onların yaydıkları ısıdan kaynaklanan güçleri vardır" şeklinde bir kavram yanılgısına da sahip oldukları tespit edilmiştir. Bağ enerjisiyle ilgili olarak, katılımcılar genellikle, bağ oluşumunun endotermik, bağ kırılmasının ekzotermik olduğunu iddia etmişlerdir. Bağ oluşumunu endotermik bir tepkime olarak sınıflandırmalarının nedeni günlük hayatla bağlantılı olarak bir şeyi oluşturmak için enerji harcanması gerektiğini düşünmeleridir. Bağlarda depolanan enerjinin bağ kırılması sırasında açığa çıkacağını düşündüklerinden dolayı da, bağ kırılmasını ekzotermik bir tepkime olarak nitelendirmişlerdir. Literatürde belirtilenin tersine öğrencilerin yanma entalpisini anlamalarıyla ilgili bir zorluğa rastlanmamıştır. Fakat bazı öğrenciler tüm yanma tepkimeleri sonucunda her zaman CO_2 ve H_2O oluşmasını beklemektedir. Bunun bir nedeni kimya derslerinde genellikle hidrokarbonların yanma tepkimelerinin sıkça kullanılması olabilir. Dolayısıyla öğrenciler tüm yanma tepkimelerini genellemekte ve bu tepkimelerin sonucunda bu ürünlerin oluşmasını beklemektedirler. Veri analizi ve mülakatlar öğrencilerin birçoğunun kalorimetre kabının nasıl çalıştığını, mekanizmasının ne olduğunu bilmediğini göstermiştir. Ayrıca, kalorimetre kabıyla ilgili olarak sistem ve çevre kavramlarının öğrenciler tarafından bilinmediği de mülakatlarla desteklenmiştir. Kimyasal tepkimelerde enerji konusunda az çalışılmış bir diğer kavram da entalpi konusudur. Bu çalışma, öğrencilerin yanma entalpisini anlamalarıyla ilgili zorlukları olmamasına rağmen, oluşum entalpisi hakkında derin bilgiye sahip olmadıklarını göstermiştir. Öğrencilerin birçoğu oluşum entalpisi ile tepkime ısısının her zaman aynı olduğunu belirtmişlerdir. Aynı zamanda, öğrenciler bir tepkimenin entalpisinin tepkimeye giren maddelerin ve tepkimeden çıkan ürünlerin hallerine bağlı olduğunun farkında değildirler. Bunlara ek olarak, tepkimenin enerji değişiminin (ΔH) pozitif olduğu durumlarda daha çok ürün elde edildiğine dair bir fikre sahip oldukları anlaşılmıştır.

Tartışma:

Bu çalışma literatürde kimyasal tepkimelerde enerji konusuyla ilgili yapılan çalışmalarla karşılaştırıldığında, elde edilen sonuçların bir kısmının onları desteklediği bir kısmının ise onlarla çeliştiği görülmektedir. Ayrıca, konuyla ilgili olarak yeni kavram yanılgıları da bulunmuştur. Bu çalışmanın sonuçları göz önünde bulundurarak, öğretmenler öğrencilerin kavram yanılgılarına göre öğretim stratejileri tasarlayabilirler. Genel olarak, kavramsal değişim modeline dayanan kavramsal değişim metinleri, işbirlikçi grup çalışmaları, gösteri ve simülasyonlar gibi öğretim yöntemleri kullanarak öğrenciler kendi bilgilerini yapılandırmak için desteklenmelidirler.