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STUDENTS' IDEAS AND MISUNDERSTANDINGS OF ENTHALPY AND SPONTANEITY: A REVIEW OF SELECTED RESEARCHES

ÖĞRENCİLERİN ENTALPİ VE KENDİLİĞİNDEN GERÇEKLEŞME HAKKINDAKİ BİLGİLERİ VE YANLIŞ ANLADIKLARI NOKTALAR: SEÇİLMİŞ ÇALIŞMALARIN BİR ÖZETİ

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ABSTRACT: This study is intended to review some of the selected researches carried out on students' understandings of enthalpy and spontaneity. The review puts together the important findings of the researches, summarises the misunderstanings identified so far and the possible sources of these misunderstandings. Therefore, this study would be beneficial for the researchers and lecturers in science education area and chemistry teachers.

Keywords: misunderstandings, enthalpy, spontaneity.

ÖZET: Bu çalışmada, öğrencilerin entalpi ve kendiliğinden gerçekleşme ile ilgili olarak yapılmış olan araştırmalardan bazılarının özetlenmesine çalışılmıştır. Bu çalışma bu alanda yapılan araştırmaların önemli bulgularını, tespit edilen yanlış anlamaları ve bunların muhtemel sebeplerini bir arada ele almış ve irdelemiştir. Bu sebeple, bu çalışmanın fen eğitimindeki araştırmacılara, eğiticilere ve kimya öğretmenlerine yararlı olabileceği düşünülmektedir.

Anahtar sözcükler: yanlış anlamalar, entalpi, kendiliğinden gerçekleşme

1. INTRODUCTION

Enthalpy is one of the fundamental thermodynamic ideas in chemistry. Students learn enthalpy generally in upper secondary school or at higher level. In secondary school, students are mainly taught the concepts 'heat' and 'chemical energy' instead of enthalpy. *Enthalpy* can be defined as '*the heat exchanged with the surroundings in the course of a reaction which occurs at constant pressure*' (Mapple 1996; p.145). Students' ideas and misunderstandings about enthalpy have received relatively little attention from science educators and researchers. Few researches carried out in order to find out students' understandings of enthalpy change or energy changes in a chemical reaction and bond energies (Boo 1998, Carson and Watson 1999, Sozbilir 2001). Therefore, in this study it was aimed to review some of the key researches and put together the misunderstandings identified so far. If science teachers are aware of the misunderstandings they will be able to better plan teaching activities and prevent new misunderstandings. Thus, this study will be of interest to science teacher trainers, researchers and chemistry teachers. It should be bear in mind that this is not a complete literature review of the research carried out on students' understandings of enthalpy and spontaneity. The research studies reviewed here are selected works and thought that best summarized the work in this area. Some of the misunderstandings identified are tabulated in Table 1.

2. THE REVIEW OF SELECTED LITERATURE

The First Law of the Thermodynamics, which states that the energy of an isolated system is constant, is taught to high school students in order to apply this in calculations of enthalpy changes in the chemical

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Table 1. Examples of students' misunderstandings of enthalpy and spontaneity

	Misunderstandings identified	*Students' age*	*Revealed By*
1	Endothermic reactions cannot be spontaneous.	17 years old, University	Johnstone et al (1977), Sozbilir (2001), Thomas (1997)
2	Viewing enthalpy as a 'form of energy'	University	Carson and Watson (1999)
3	Incomplete definition of enthalpy change	University	Carson and Watson (1999)
4	No heat occurs under isothermal conditions	University	Thomas (1997)
5	Bond breaking release energy, conversely bond making requires energy	15-18 years old, University	Barker and Millar (1996), Boo (1998), Sozbilir (2001)
6	A chemical reaction is spontaneous, if we do not need to interfere.	University	Selepe and Bradley (1997), Ribeiro *et al* (1990)
7	A chemical reaction is spontaneous, if it is observable.	University	Ribeiro *et al* (1990)
8	Spontaneous reactions occur rapidly	University	Selepe and Bradley (1997)
9	No activation energy required in spontaneous reactions	University	Selepe and Bradley (1997)
10	Spontaneous reactions occur when heat evolves from the system to the surroundings	University	Selepe and Bradley (1997)
11	Confusing lattice enthalpy and hydration enthalpy.	University	Sozbilir (2001)
12	Dissolution process is always exothermic/ endothermic.	University	Sozbilir (2001)
13	Formation enthalpy is always exothermic.	University	Sozbilir (2001)
14	A spontaneous reaction is always exothermic.	University	Sozbilir (2001)
15	Enthalpy change is the energy transfer at constant volume.	University	Sozbilir (2001)
16	Exothermic reactions occur fast.	University	Sozbilir (2001)
17	Endothermic reactions occur fast.	University	Sozbilir (2001)

reactions (Barker 1995, Barker and Millar 1996). It is a basic idea that energy is released when bonds form and energy is required to break the bonds. Studies show, however, that students' understanding is often the opposite of this (Barker 1995, Boo 1999, Sozbilir 2001).

High school students' ideas about thermodynamic concepts such as enthalpy, entropy and free energy were addressed by Johnstone, MacDonald & Webb (1977). In order to reveal the conceptual difficulties experienced by students, they wrote a *thermodynamics approach* test which was given to 98 pupils from ten different schools. The results showed that approximately one pupil in six had the misunderstanding that endothermic reactions can not be spontaneous. They attributed this to the universal rule that situations tend spontaneously to a lower energy position. They also noted that this misunderstanding was not new and historically there was a belief held by the famous chemists, Berthelot and Thomsen in 1878, that reactions have to be exothermic to be spontaneous. They suggested that this kind of misunderstandings could be overcome by teaching in a small group of students. A large lecture class is not the best medium for the presentation of thermodynamic concepts. It was also reported in an another research carried out with university students that the same misunderstanding in 75% of the college students who took the physical chemistry course and 60% of the students thought that no heat transfer occurs under isothermal conditions (Thomas, 1997).

In a more recent study Carson and Watson (1999) studied first year chemistry undergraduates' understandings of 'enthalpy change' and found that students viewed enthalpy as a 'form of energy'. In addition, none of their sample was able to associate work with chemical reactions and the concept of 'pV work' was unknown. Moreover, it was found that 9 out of 16 students were not able to give precise definition for

enthalpy change. Their definitions were restricted to a specific type of reactions such as neutralisation. In the same study students also were asked about common thermodynamic mathematical expressions but found that many of the students did no more than recognize the names of the symbols.

Ross (1993) identified that many students thought that energy is released when chemical bonds break in contrary to the chemists' view. Ross suggests that these misunderstandings arise due to the association between fuels and energy developed by students and that this is a barrier to learning the concepts. He argues that misuse of terms in everyday life causes students to develop misunderstandings and therefore words should be chosen carefully in teaching. Additionally, students should be given more time to reinterpret, use and apply the new ideas in their science lessons. Barker (1995) studied A-level students' ideas about thermodynamics and found that only 1 in 5 beginning A-level students thought that bond breaking released energy, and conversely bond making required energy. This was the similar to the findings of Ross (1993). She attributes this to the fact that fuels are taught to be 'energy stores'.

Spontaneity and reaction are the other concepts in chemistry that are generally confused with their everyday meanings. Ribeiro, Periera & Maskill (1990) define these two terms:

> A chemical reaction is a material process in which a new substance is formed. A spontaneous reaction is one which has a natural tendency to occur; one which has products with lower free energy than the reactants (10; p.392).

In order to find out how fourth-year undergraduates in chemistry interpret the chemical phenomena using the words *reaction* and *spontaneous* Ribeiro, Periera & Maskill (1990) conducted a clinical interview study with 14 students. The students were shown four experiments related to the topic and then they were asked about the phenomena. The results revealed that the majority of the students used the everyday notion of the word 'spontaneous', thus the word 'spontaneity' was related to observable features such that *a chemical reaction is spontaneous if it is observable*. The findings also revealed another misunderstanding that *a chemical reaction is spontaneous if we do not need to interfere*. According to them, the main source of these misunderstandings is everyday use of the words. It was stressed that science teachers must pay careful attention to everyday, out-of-class ideas associated with the concepts. Another suggestion was that students should be helped to see clearly the contextual differentiation of their knowledge. The final comment was that students should be given closer guidance when they are trying to apply theoretical knowledge to practical situations. It is argued that conventional lectures and laboratory classes may not be the best vehicles to overcome these misunderstandings.

In another study Selepe and Bradley (1997) investigated 56 final year college student-teachers' ideas and areas of conceptual difficulties in thermodynamics. They used questionnaires and interviews. Their research revealed similar misunderstandings as with Ribeiro, Periera & Maskill (1990), but also some new ones such as that spontaneous reactions occur rapidly, have no activation energy, and spontaneous reactions occur when heat evolves from the system to the surroundings. They also found that the sign of the change in enthalpy was used as a determinant for spontaneity. They argued that everyday usage of the word 'spontaneity' which means 'immediate action or rapidity' causes misunderstandings in students.

In a longitudinal research project, Sozbilir (2001) studied total 91 Turkish chemistry undergraduates' understandings of enthalpy idea from two different universities. A diagnostic questionnaire and interviews were used in order to probe students' knowledge of enthalpy. The study revealed several misunderstandings including some of the previously identified misunderstandings such as *bond breaking releases energy and bond making requires energy* and *endothermic reactions cannot be spontaneous* and some new misunder-

standings such as *confusing hydration enthalpy and lattice enthalpy*, *dissolution process is always endothermic or exothermic* suggesting that students have no clear conception of energy changes involved in dissolution processes. It was speculated that this misunderstanding may arise from students thought that the dissolution process only consisted of breaking of the intra-molecular bonds in water, which requires energy, and this resulted in the misunderstanding that *dissolution is an endothermic process*, or if they thought that the second stage of the dissolution which is the hydration of the dissolved ions in the water is an exothermic process, this resulted in the misunderstanding that *dissolution is an exothermic process*. It was also reported that students had difficulty in differentiating the dissolving and dissociation processes. The results suggest that students are likely to make over generalizations by relaying on data representing only one or two cases.

Furthermore, Sozbilir (2001) found out that students appeared to understand that the source of the energy is different in exothermic reactions and endothermic reactions. Only a small number of respondents were aware of the fact that chemical bonds are the energy stores and therefore the energy change of a reaction is related to the strength of the bonds broken and made in a reaction.

Moreover, Sozbilir (2001) also revealed that undergraduates have an incorrect conception that *formation enthalpy is always exothermic*. It was argued that this misunderstanding is more likely to originate from the fact that most of the formation reactions are exothermic (p. 306). In addition it was made explicit that students thought *spontaneous reactions have to be exothermic* and related to this, *endothermic reactions cannot be spontaneous* as discussed above. There was also common misunderstanding that identified by Sozbilir (2001) that states *enthalpy change is the energy transfer at constant volume*. The researcher found that this misunderstanding is originated from the lack of understanding of constant pressure and constant volume cases in chemical reactions, difficulty in differentiating heat and temperature and energy transfers involved in chemical reactions (p.306).

Finally, Sozbilir (2001) identified that students thought that *exothermic or endothermic reactions occur fast*. This misunderstanding was common among the quarter of the subjects and indicates that students tend to confuse the kinetics and thermodynamics of a chemical reaction easily.

3. CONCLUSION

In conclusion, the studies on students' ideas of enthalpy and spontaneity are inadequate since there are few systematic studies carried out to determine the students' understandings of these concepts. Advanced studies on university students' ideas about the relationship between the reaction enthalpy, reaction rate, spontaneity and activation energy and enthalpy change would yield useful results and would be beneficial for the researchers and the teachers of chemistry.

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