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Two Ideas of Redox Reaction: Misconceptions and Their Challeges in Chemistry Education

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Abstract: *In interpretations of chemical phenomena students particularly of Secondary School level like to mix substances from the macroscopic level, that is substances that can be seen, touched and smell with particles from the sub-micro level; atoms, ions, molecules etc. "hydrochloric acid is giving one proton" (instead of "One H_3O^+(aq) gives one proton"). For redox reactions students are doing this too: "one Copper two ions takes two electrons and is reduced to Copper": (instead of "to one Copper atom"). That is Cu_2^+ ion + $2e^-$ $\longrightarrow$ Cu atom. Another difficulty seems to be the historical redox definition with the "Oxygen transfer", this idea is so attractive that students argue most with Oxygen participation instead of the transfer of electrons. On the one hand the students do not see any connection between both levels; on the other hand it is left up to them to figure out which mental model they may choose concerning the sub-microscopic level. They are building up ideas on their own, mostly wrong ones. This paper reflects those misconceptions and proposes way of instructions that will serve as a preventative measure against such school – made misconceptions.*
Keywords: *Redox Reaction, Misconception, Chemistry Education.*

I. Introduction

Chemistry is world filled with interesting phenomenon, appealing experimental activities, and fruitful knowledge for understanding the natural and manufactured worlds (Chiu, 2005). However, it is so complex, not only do students need to understand the symbols, terminologies and theories used in learning chemical concepts, but they also need to transform instructional language or materials that teachers use in chemistry classroom into meaningful representation.

Research in science teaching has indicated misconception contributing on student learning outcome. Misconception is not a simple problem and can not be taken for granted. Numerous studies have shown that misconceptions concerning many aspects of chemical phenomena are prevalent among students. (Cole & Todd, 2003). In a study conducted by Hesse & Anderson (1992), they observed that the effect of Oxidation and reduction was a difficult concept for students to conceptualize. Students believed that the Oxygen that made the iron to rust was from water and that rusted iron had the same weight as the original iron. Herron, (1996), argued that language in Chemistry make learning difficult because the meanings of some words in Chemistry are different from the language used in daily life. Misconceptions can raise from the models used in the textbooks which only proved explanations of phenomena, and they have their strength and limitation (Oversby, 2000 and Kikas, 2004).

In modern Chemistry education the redox reaction is defined by an election transfer as with metal – nonmetal reaction see fig. 1 or with the reaction of ion and Copper Sulphate solution see fig. 2. In these examples, the reactions can be explained by electron transfer from metal atoms to nonmetal atoms or of metal atoms or metal ions – it is correctly argued with involved atoms and ions (see fig. 2.

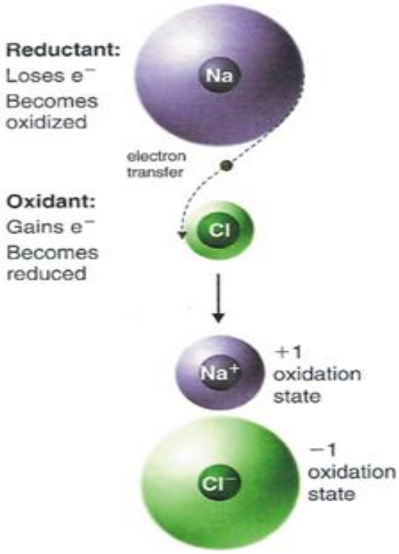

Figure 1: model of the reaction of metal atoms with non-metal atoms by electron transfer.
(Averill, B. & Eldredge, P., (2007).

Oxidation:	Fe atom $\longrightarrow$ Fe^{2+} ion + $2e^-$
Reduction:	Cu^{2+} ion + $2e^-$ $\longrightarrow$ Cu atom
Redox:	Fe + Cu^{2+} (aq) $\longrightarrow$ Cu + Fe^{2+} (aq)

Figure 2: Reaction of metal atom on metal ions

If you ask, however, students at the beginning of their studies in Chemistry, one is astonished that mostly the iron – cupper sulphate experiment is not reflected on the basic of atoms and ions but of substance: “Copper is oxidized to Copper II Oxide and is deposited on the iron nail; iron is oxidized and Copper Sulphate is reduced; iron is oxidized and takes “O” from the $CuSO_4$; electrons are released and Oxygen is absorbed” (Barke, 2012).

This paper addresses the question of misconceptions according to the two well known redox definitions and tries to analyze and compare those erroneous answers. It also proposes ways which should ensure misconception prevention and also provide misconceptions prevention.

II. Misconception and its Identification

Skelly and Hall, (1993), defined misconception as a mental representation of concept that does not corresponds to a correctly held scientific theory. Cambridge dictionary defined misconception as an idea that is wrong because it has been based on a failure to understand a situation (dictionary.cambridge.org/dictionary…). Misconception is divided into two categories:

1. Experimental and
2. Instrumental

In an experimental misconception concept has been understand, at least to some extend, through every day experience and interaction with the phenomenon involved. Instrumental misconception however, is pertaining to more abstract phenomena result from some instrumental experience: Committee on Undergraduate Science Education, (1997), categorized misconceptions into five groups.

- Preconceived nations
- Non-scientific belief
- Conceptual misunderstanding
- Vernacular misconceptions
- **Preconceived notions**: are popular conceptions rooted in everyday experience.

- **Non-scientific beliefs**: include views learned by students from sources other than scientific education, such as religious or mythical teaching.

- **Conceptual misunderstanding**: develops when students are taught scientific information in a way that does not challenge them to confront paradoxes and conflicts resulting from their own preconceived notions and non-scientific belief.

- **Vernacular misconceptions**: arise from the use of words that mean one thing in everyday life and some thing else in scientific contexts.

- **Factual misconceptions**: are falsities often learned at an early age that remain unchallenged into adulthood.

Therefore, misconceptions can distract students' concepts construction process in their cognitive structure. For that, it is so important for teachers to know their students misconceptions so that they can carry out misconception remediation. (staff/ung.acold/siter/default/filesion)

Redox Reactions

The teaching of redox should begin with the information that the term redox is coined from the words reduction and Oxidation. This is because the two processes occur simultaneously in the same reaction (Achimugu, 2009, National Research Institute for Chemical Technology, NARICT, 2010). These reactions involve the transfer of Oxygen or hydrogen atoms or electrons from one unit of matter to another (Udo, 2011). Basically, there are two types of redox reagents used in redox reactions: reducing agents and oxidizing agents. In a redox reaction.

- A reducing agent (a reductant or reducer) is the substance that loses or donates electrons, or gets oxidized; whose oxidation number increases.
- An oxidizing agent (an oxidant or oxidizer) is the substance that gains or accepts elections, or gets reduced; or whose oxidation number decreases (NARIC, 2010).

Hence redox reactions could be defined in terms of electron, hydrogen or oxygen transfer, or in terms of change in the oxidation state of the species in the reaction. Common example of redox process are burning of substance, rusting and dissolution of metals, the borrowing of fruits; respiration and photosynthesis (Olson, 2010).

Consider the combustion of carbon

$$C + O_2 \longrightarrow CO_2$$

(O.N) 0 0 +4 ⁻ 2

R.A O.A

Where O.N = Oxidation number
R.A = Reducing agent
O.A. = Oxidizing agent

The oxidation number of carbon has increased from zero (0) in elemental carbon to +4 in CO_2; this is oxidation. Carbon is a reducing agent; it has been oxidized to CO_2. The oxidation number of oxygen atom has decreased from zero (0) in O_2 to ⁻ 2 in CO_2; this is reduction. Oxygen gas is an oxidizing agent; it has been reduced to an oxide, CO_2.

Unfortunately, despite the importance of redox reaction in Nature, technological development and every day life, both students and teachers of chemistry consider the concept difficult (Udo, 2011). In a study report conducted by WAEC, 2003, Njoku, 2004, Ojokuku & Amadi, 2010), shows that students perform poorly in the concept area at public examinations at the secondary school level. Common areas of misconceptions include the students' inability to write the correct equation for reaction, determination which species is oxidized or reduced, determine the oxidation state of the species involved in the reaction, write a balanced equation for the reduction and oxidation half reaction correctly, or balance correctly a given **redox** equation.

Redox and Oxygen Transfer

In many curricula of schools the oxygen transfer is instructed as the first central idea concerning combination processes and the participation of oxygen. Schmidt, (1994) interviewed several thousand students of secondary education, which one of the following reactions should be a redox reaction:

i. $2HCl + Mg \longrightarrow MgCl_2 + H_2$
ii. $2HCl + MgO \longrightarrow MgCl_2 + H_2O$
iii. $2HCl + Mg(OH)_2 \longrightarrow MgCl_2 + 2H_2O$

about half of the students chose the correct answer (i). the remaining participants were not sure about this and chose the reaction (ii) or (iii) or both (that are acid – base reactions), and delivered reactions such as "MgO and $Mg(OH)_2$ contain oxygen, what is absolutely necessary for redox reactions; to any redox reaction "O" is necessary – so choice (i) cannot be a redox reaction". These students include the syllable "OX" on the participation of oxygen (Barke, 2012), – even if the election transfer was taught in classes and the oxygen reaction has been declared a special case of redox reaction.

III. Iron – Copper II Tetraoxosulohate (VI) Solution

In a study conducted by Sumfleth, (1992), examined statements of students in grades 6 – 13 made to the well known reaction of an iron nail in copper sulphate solution. She gathered a lot of wrong answers, which were based on pre-concepts and school – made misconception. They described the emergence of a copper – coloured coat with "setting, hanging or sticking or staining a substance on the iron nail". Interpretations related to every day life are: Copper Sulphate sticks on the nail; it stuck, it glues on the nail like colour on a piece of wood and then dries up" (Sumfleth, 1992). Half of the students suspected an attraction as the cause of the red substance; other substance, other students mentioned an existing magnetism – probably because of the iron nail. Those students just described their observations in other words, that were non-scientific ideas.

However, even on the advanced level there are misconceptions, only interspersed with specialized scientific terms "Copper dissolves from the sulphate and binds to the iron; Copper Sulphate is reduced: Copper atoms attracts electrons; iron nails can absorb the ionic solution" (Barke, 2012). These statements demonstrate that special terms of the scientific terminology are indeed learned and the students feel the urge to use them well.

Heints, (2005), uses redox idea and developed an instrument and presented a 15 – questions questionnaire to students in grades 10 – 12 in some schools of the area of Muenstar in Germany. From the questionnaire problems are taken as examples for the article.

Metal – Oxygen Reactions

In this task the students are expected to describe their ideas on metal – oxygen reactions. This task want to measure whether the simple oxygen definition or the enhanced electron transfer theory is used by the students, in what cases and to what extent they argue with substances or with atoms, ions or molecules.

Task 1:

A piece of copper sheet is folded to a small envelope and heated with roaring flame the outside of the sheet turns black, after opening the envelops the inside remained copper – coloured.

a. a combustion reaction takes place,
b. the outside is made from black soot,
c. a redox reaction occur,
d. copper atoms change their colour.

Explain your answer

With 59% of makings the destructor (B) was the most attempted choice, but only 21%, gave the right answer (C), options (A) and (D) were chosen by 18% and 4%. Many students combined option (B) with (A), some times with (C), this is probably due to the lack of practical experimentation. That showed that many students don't know the "roaring flame" and what it means. The reasons given for option (B) are "by the flame/through combustion/fire is formed soot, burns outside the copper plate, copper oxidizes, the soot is copper II oxide".

Also the role of oxygen for the combustion is not clear for the students; they are looking for everyday life explanations: "oxygen is burned and soot is deposited; oxygen is burned and carbon IV oxide is produced, the combustion leads to three products: CO, CO_2, C". When the advanced students have chosen the right answer "redox reaction", so they didn't have outlined any electron or equations partly for electron release and electron acceptance.

Task 2:

For the production of iron in the blast furnace tri-iron tetra-oxide (Fe_3O_4) and coal (C) are necessary, by heating the mixture strongly, the liquid iron is running out with glaring light.

a. carbon is a catalyst,
b. a redox reaction takes place,
c. iron oxide is reduced.
d. iron oxide decomposes into elements.

Explain your answer

Blast furnace process. This task describes the production of iron through the reduction of iron oxides by coal which is well treated in nearly every chemistry instruction. The responses pattern is characterized by the almost equal percentage distribution of answers; the correct answer (B) was only given by 20% of the students a sufficient explanation by only 4%. By their explanation almost nobody argued with electron transfer, but usually with oxygen transfer' and equations in words, or (often completely wrong) with reaction equation and the "change of oxygen atom" like in this equation.

$$Fe_3O_4 + 2C \longrightarrow 3Fe + 2CO_2$$

Other reasons are: "coal reacts with oxygen from iron oxide to form CO2, iron is left; by the carbon combination oxygen is needed, which is taken from iron oxide". Mostly the answer (A) was chosen and justified as follows: Carbon only helps to get the reaction going, but it does not react, carbon supplier the heat is necessary for the decomposition of iron oxide (Barke, 2005).

IV. Prevention of Misconceptions

Misconceptions are not only to be observed in today's students, even scientists and philosophers developed and lived with many misconceptions in the past. Historical concepts and their changes are very interesting because similar ideas can help our students today. Just like early scientists did they develop their own concepts by similar observations e.g. in regard to combustion ideas that developed without having any prior knowledge of subjects are not necessarily, wrong but can be described as alternative, original or pre-concepts. Every science teacher should know these pre-concepts for his or her lesson.

The selection of learning models to prevent students' misconception is very important. This is in accordance with Pekmez's (2010), the selection of teaching methods is an important factor in preventing students misconceptions. By inquiry approach, for example students are given greater opportunities to learn chemistry concepts by netting (nested) common exercise of thinking skills that are commonly done by scientists, students are expected to comprehend the way scientists working and thinking so gaining the insight according to scientists understood, students have no chemistry misconceptions. Bathlow, (2011) have shown positive results of this idea that through scientific inquiry learning; students chemistry misconceptions can be replaced to the true concept.

Both, pre-concept and scientific thinking are stored in "compartments" in separate areas of cognitive structure. Teachers cannot automatically assume that in a particular lesson any pre-conceptions regarding his/her lesson will disappear. It is necessary to diagnose such concepts and, in the case of misconception, to plan a lesson which integrates new information with these concepts. Another important task is to make suggestion of instructional strategies to improve pre-conceptions and school-made misconceptions. Recommending alternative strategies to traditional approaches, setting up convincing laboratory experiences, using more structural models or technology – based method, inappropriate teaching method can be stopped by keeping teachers up – to – date in their subject through advanced education. One should attempt to find as many pre-concepts and school – made misconceptions and discuss them with their students.

Improvement of student misconception through remediation program are an inedibility because there is evidence that prevention efforts using various learning models recommended by various expects still leaves students misconceptions. According to Trumber, (1997), a learning cored conceptual change can be considered as a strategy to reduce student misconception.

V. Conclusion

The terms oxidation, reduction and redox reaction are central for understanding chemistry: they must be taught best. With the redox idea students can interpret a lot of everyday life phenomena. Combustion phenomena, the rusting of iron and other corrosion processes, the production of iron in the blast furnace, etc.

This is proceed in steps: the first step in the beginning of teaching burning process the concepts of oxidation and reduction on the level of oxygen transfer are possible, substances are oxidized or reduced. The reactions should by show experimentally and it can also be described in word equations, but not in formulas. One may also be thinking of the term "redox" and it is not suppose to be in this context.

The extended redox idea should now be taught in the second step with the word "redox" the electron transfer is linked and described by particles. Metal atoms are oxidized to ions, other ions are reduced to atoms, part equations for oxidation and reduction should show the numbers of transferred electrons. Model drawings may visualize those chemical processes, and not only redox, also many complex reactions, Acid-base reactions could also be taught. Science teachers particularly chemistry should not forget to integrate misconceptions into lectures, the students know with those discussions what is right or wrong.

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