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Concept of chemical reaction in chemistry textbooks

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Abstract:

For more than 20 years the science teachers, the researchers in science education, the educationists and the other pedagogues have been acquainted with the model of educational reconstruction. In this model there are integrated three areas of this scientific interest: the recognition of pupils' conceptions, the investigation of scientific conceptions with didactics branch approach and the creation of an educational content (Duit, R., Gropengießer, H., & Kattmann, U. (2005). Towards science education research that is relevant for improving practice: The model of educational reconstruction. In H. E. Fischer, (Ed.), *The Developing standards in research on science education* (pp. 1–9). London: Taylor & Francis; Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The model of educational reconstruction – a framework for improving teaching and learning science. In D. Jorde & J. Dillon (Eds.), *Science education research and practice in Europe. Cultural perspectives in science education*, 5 (pp. 13–37). Rotterdam: Sense Publishers; Kattmann, U., Duit, R., Gropengießer, H., & Komorek, M. (1997). Das Modell der Didaktischen Rekonstruktion – Ein Rahmen für naturwissenschafts-didaktische Forschung und Entwicklung. *Zeitschrift für Didaktik der Naturwissenschaften*, 3(3), 3–18). There is required to reconstruct the educational content for learning and teaching purposes. It leads to the educational structuring and to the clarification in scientific field. Therefore, in this contribution there is analysed a formation of the concept chemical reaction from the perspectives of the chemistry textbooks used in the 19th, the 20th and the 21st centuries in Slovakia. These findings could be useful in the process of comparison between scientific and pedagogical knowledge in this branch not only in neighbouring countries, even in the broaden European or worldwide content.

Keywords: chemical reaction, educational reconstruction, textbook content analysis

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Introduction

For last 20 years, many educational researchers have been focused on educational reconstruction (Jelemenská, Sander, & Kattmann, 2003) by analyzing and re-evaluation of the science teaching content at primary and secondary schools in Slovakia and even more in other central European countries. It is connected with a researchers' effort to the complete understanding of the individuals' cognitive ontogenesis and also to the acquaintance of phylogeny of particular concepts. The simplification and the reduction of the scientific concepts explanation (Knecht, 2007) do not mean automatically the holding of the concept nature and its depth but often it leads to the misunderstandings and misapplications in practice. Therefore, there is reasonable the thoroughly approach to the making the content available to pupils and students. It is important to find out their current content knowledge as well as the cognition of historical background and the basis of science key concepts. The educational reconstruction (Jelemenská et al., 2003; Kattmann, Duit, & Gropengießer, 1998) is one of the contemporary approaches, which is connected with mediation of the scientific content to pupils. This approach was presented for the first time in 1997 by professor Kattmann. Its importance is connected with the fact, that it does not only include the selection of a suitable scientific content and, subsequently, its mediation to pupils, but it focuses mainly on the systematic identification of pupils' assumptions and conceptions about the scientific knowledge available to them (Knecht, 2007). Pupils' conceptions as the subjective mental constructions those come from their everyday experience are not understood as the obstacles or the barriers, but as the useful learning tools (Jelemenská, 2009). The findings are compared or confronted with the knowledge that was relevant in the past and which is up-to-date nowadays. The result of this approach is then the reconstruction of educational content taking into account the objectives of the educational process, pupils' ideas and scientific knowledge (Knecht, 2007). The subject of teaching is not knowledge given by scientific field and which can be

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pedagogically shaped into a complex form. The purpose of the educational reconstruction is to connect scientific knowledge with interdisciplinary knowledge and with pupils' experience, their attitudes, their value system and their comprehension. The educationally reconstructed school subject represents more complex educational content, not only simplified or didactically reduced one. It proceeds in three steps: summarization, explication, structuring. The educational reconstruction includes a supporting of meaningful learning. The mission is to inquire and to discover important relation and bonds between scientific knowledge and learning conditions of individuals. There are influenced by their motivation, social conditions and cognitive level (Kattmann, 2009). Therefore, there should be created the opportunities during the teaching scientific content, to be possible to confront and evaluate critically the results of learning process. Pupils would be able to recognize the reasons for scientific appropriate understanding of reality (Jelemenská, 2009).

Methodology

The idea of the historical way of understanding scientific concepts in different scientific field is one of the principal postulates of the educational reconstruction concept. Such a historical excursus shall help in the prediction of probable mental processes, obstacles, difficulties and manners how to overcome a priori conceptions in the way of deeper science concepts understanding. A certain analogy between the scientific knowledge phylogeny and individual knowledge ontogenesis is presumed. From our point of view, the historical excursus is needed because of the progress of educational concepts during the knowledge development in educational system. It is important especially for teachers, who are preparing their own models of forming concept in pupils' minds. According to the historical changes of forming the particular concepts in teaching subject the teacher better see and understand the requirements of scholar practice and his own approach is then more inventive. That was the reason we decided to study the content of chemistry textbooks which were used in Slovakia in the past and which are used today. We were focused on the phenomenon of chemical reaction in our searching. We were monitoring several approaches to the understanding of the concept of chemical reaction. The textbook content analysis was used as a research method. The way of making the construct understandable according to the pupil's age, the type of school he/she attends was the aim of research in analysis of the accessible chemistry textbooks (and their historical equivalents). The historical aspect of concept chemical reaction is presented in more than 100 years period including its composition into other basic chemical knowledge, into the source concepts and associated concepts (Prokša, 2017). We compared the chemical content in textbooks from the 2nd half of 19th century with the explanation of the concept of chemical reaction 100 years later. Nowadays understanding presented in textbooks is offered too. The content analysis of these selected textbooks will show how the knowledge has evolved over time.

Analysis and results

Our attention was focused on the chemistry textbook content analysis with the aim of studying the development of a concept of chemical reaction from the historical point of view. We analysed the available chemistry textbooks, even the biology and the physics (or historically strength-teaching) textbooks, where the key concept and the chemistry content appeared and was explained in the past. The concept chemical reaction has been specified and precised for many years and during the centuries. The chemical phenomena, precisely the chemical reactions were not exactly defined in the textbooks used in the 2nd half of the 19th century between the years 1869 and 1899 (Table 1). The examples were not written in symbolic way, just verbally described. People were conscious that except the physical phenomena there are existing other ones. In the Zoch's textbook published in 1869 it was written, that many of the natural scientists consider the mixing like a combination, but the discrepancy in this claim is that the combination of atoms and elements is happening according to the certain exactly defined ratio, while the mixing can occur in any ratio. There was written about the phenomena and processes of everyday life in the textbooks from the 2nd half of 19th century. That was important for an industrial production of the substances and for practice information about a preparation of different metal alloys (a steel, a brass, an amalgam, etc.) could be found there. It was known that the rare metals such as gold, silver, platinum do not rust and do not combine with acids, even iron and copper corrode when the air humidity works. It was also known that the acidic substances react with the copper because of forming the poisonous compound ("greencopper"¹). It is the reason why the copper objects should be protected what is done by the tinning. The process of the burning lime and the slaking lime production, even so the processes such as the burning, the fermentation and the putrefaction were mentioned in the textbooks. There was described the breathing process, with the carbonic acid producing in the blood of the living creatures by combination of an oxygen and a carbon.

Several years later there was noticed the process when the plants received the carbon acid from environment and produced an oxygen (the photosynthesis). It was known, that the air consists of an oxygen, which helps in the burning process and it is important for life, and of a nitrogen, which does not promote in the burning process, nor in the living. Information what appeared in textbooks of that days and was incorrect according to the current scientific knowledge referred to processes of the burning, the breathing, the fermentation and the putrefaction, that the carbonic acid is formed. Another one was about forming of the sulphurous acid during the burning process of a match. The schemes and the chemical equations were not utilized for a notation of the chemical phenomena, also the illustrative pictures were missing in textbooks in the past. The chemical nomenclature was different in comparison to that is used now.

Table 1: The key concepts and the connotations to the concept of chemical reaction in the analysed chemistry textbooks from the 2nd half of the 19th century.

Textbook (author, title, year of publishing)	The key concepts and the connotations to the concept of chemical reaction
Ivan Branislav Zoch Physics or Strength-teaching 1869	<ul style="list-style-type: none"> – the mixing is sometimes considered as combination process, but the mixing can occur in any ratio and the combination of atoms and elements is happening according to the certain exactly defined ratio – known the production of a brass, a gunpowder, a nitrohydrochloric acid, a steel, an amalgam – the chemical effects of the light, which stimulate the decomposition and the combination of the substances
Ivan Branislav Zoch Physics or Strength-teaching 1870	<ul style="list-style-type: none"> – the chemical effects of the light, which stimulate the dissociation and the combination of the substances – developing of the photographs
Gustáv Kordoš Brief natural history for Slovak national schools 1871	<ul style="list-style-type: none"> – the production of the burning lime from the limestone – the modification of the sour wine with the lead acetate – a mercury dissolves the rare metals – gold and silver – gold, silver, platinum do not rust and do not combine with acids – the preparation of the alloys (a brass, an amalgam, an alpaca, etc.) – an acid (vinegar, sour food) react with the copper forming the poisonous compound (“greencopper”) – during the heating process of stone-coal the gas (used for lighting) and the coke are formed
Ján Kožehuba Natural history for national schools 1872	<ul style="list-style-type: none"> – an acid (vinegar, sour food) reacts with the copper forming the poisonous compound (“greencopper”) – forming of the choking gas, the sulphurous acid during the burning process of a match – when the limestone is poured by an nitrohydrochloric acid a foam appears, it is in boil and acid is formed – when the water and air humidity effect an iron the rust is forming – an iron in the cement water is changed into a copper – the tinning of the copper cans

Gustáv Kordoš
Simple folk physics, strength
teaching for school and
household in inductive method
1872

- the burning (using the lens, sun, by rubbing), burning conditions
- the slaking process of the lime
- the combination of varied substances produces a heat
- during the heating process of stone-coal the town gas and the coke are formed
- the air consists of an oxygen (which is maintaining a fire) a nitrogen and a carbonic acid (what are not keeping a fire)
- while breathing we breath an oxygen in and a nitrogen returns back not used
- an oxygen can be prepared from tree leafs shined by the sun or by heating of the potassium chlorate
- when a very hot coal is within easy reach of an oxygen a carbonic acid (an invisible gas) and heat are forming
- the carbonic acid is forming by the burning of wood, lamps, candles, by the rising of the dough, by breathing
- the chalk poured of sulfuric acid produces a carbonic acid
- an oxygen combines with an iron to form rust, with copper to form the green copper, with the sulphur to form sulphuric acid
- an oxygen combines with hydrogen to water, the mixture of gaseous hydrogen and oxygen is explosive
- water reacts with pieces of an iron and sulphuric acid to form gaseous hydrogen and a rust
- calciferous (saline) water is not eligible for washing, cooking; the soap does not dissolve and the meat does not become tender
- water can be purified by the coal powder
- a hydrogen is forming in swamplands
- a hydrogen is forming fen-fire with the phosphorus

Gustáv Kordoš
Brief physics or strength teaching
for Slovak national schools in
inductive method
1873

- the slaking process of the lime (pouring the water on the burning lime the heat is produced)
- the burning process and the burning conditions
- by the combination of varied substances produces a heat
- during the heating process of stone-coal the lighting gas (town gas) and the coke are forming
- the air consists of an oxygen (which is maintaining a fire) a nitrogen and a carbonic acid (what are not keeping a fire)
- an oxygen can be prepared from tree leafs shined by the sun
- while breathing we breath an oxygen in and a nitrogen returns back not used
- if the hot coal is put into oxygen, it produces carbonic acid (invisible gas and heat)
- the carbonic acid is formed by the burning of wood, lamps, candles, by the rising of the dough, by breathing
- water reacts with pieces of an iron and sulphuric acid to form gaseous hydrogen and a rust
- water is substance which consists of a hydrogen and a n oxygen
- a hydrogen is forming in swamplands
- a hydrogen is forming fen-fire with the phosphorus

Ján Bežo
Strenght teaching or Physics for
national schools
1873

- chemistry, deals with phe phenomena that arise by decomposition of compounds and the combination of the elements
- the air consists of an oxygen (which is maintaining a fire) a nitrogen (what is not keeping a fire)
- the burning process and its conditions, the rising of the dough
- an oxygen can be prepared from tree leafs shined by the sun (photosynthesis)
- the combining of a carbon and an oxygen forms carbonic acid (gas), hydrocarbon, water; the explosive mixture
- carbonic acid is forming by the burning process, by the decaying, by the rising of the dough, by the breathing
- the plants take up carbonic acid and release an oxygen
- the charcoal is used for purifying the substances
- the combustible substances consisted of oxygen, hydrogen and carbon decompose during the urning process to form steam and hydrocarbons
- all metals except gold and silver are combined with the oxygen on the air
- a hydrogen is forming in swamplands
- in burning of a sulphur the smelly gas is forming sulphurus acid, which destroys a mould

<p>Gustáv Kordoš Brief physics or strength teaching for Slovak national, Sunday and repeted schools in inductive method 1874</p>	<ul style="list-style-type: none"> – the burning, burning conditions – an oxygen can be prepared from tree leafs shined by the sun (photosynthesis) – the air consists of an oxygen (which is maintaining a fire) a nitrogen and a carbonic acid (what are not keeping a fire) – while breathing we breath an oxygen in and a nitrogen returns back not used – when a very hot coal is within easy reach of an oxygen a carbonic acid (an invisible gas) and heat are forming – the carbonic acid is forming by the burning of wood, lamps, candles, by the rising of the dough, by breathing – water reacts with pieces of an iron and sulphuric acid to form gaseous hydrogen and a rust – an oxygen combines with a hydrogen to water – a hydrogen is forming fen-fire with the phosphorus – a hydrogen is forming in swamplands – during the heating process of stone-coal the lighting gas (town gas) and the coke are formed
<p>František Otto Matzenauer Brief natural history for Slovak national schools 1874</p>	<ul style="list-style-type: none"> – an oxygen is needed for breathing, living and burning – the combination of an oxygen with other minerals the acids are forming – the mineral water consists of an oxygen and a hydrogen – a carbon combined with an oxygen forms carbonic acid (gas), that forms in the fermentation – the carbonic acid is in old waterwells, mines, in the closed cellars – the precious metals (gold, platinum, silver, mercury, aluminium) do not rust on the air and do not combine with acids – the iron is rusting on the air – the iron with match forms pyrit – the copper lightly becomes infected by every acid and forms very poisonous green substance ("green copper") – ammonium chlorid (salmiac) is formed from seasalt, urine and decaying the animal remains – the ammonia is known
<p>Pavel Seidel Pictorial natural history for national schools 1874</p>	<ul style="list-style-type: none"> – the burning process – the copper cans needed to be tinned, protecting from the rust – lead boils into lead sugar used for rectifying the sour wine
<p>Heribert Ertl Textbook for Slovak everyday and repeated folk schools 1893</p>	<ul style="list-style-type: none"> – the burning process – an iron is going to be rusty on air – gold does not rust – the production of alloys (steel) – a feldspar is falling into pieces of loam needed for making porcelain
<p>Ján Györfy The natural history according to the ministry schedule for pupils of folks schools 1899</p>	<ul style="list-style-type: none"> – the match is burning in the blue flame choking gas is smelled – the limestone poured with vinegar acid is fizzing, – the burning process of lime – the slaking process of lime – a feldspar is falling into pieces of a white loam needed for making porcelain – an iron, a steel, a copper are going rusty on air humidity – gold, silver, platinum do not rust – known the production of the alloys: a steel, a bronze, a brass – an iron, a gold, a silver are melting in large fire, – a mercury is vaporizing by heating and is freezing in cold

The concept of the chemical process or rather the chemical reaction is mentioned in the chemistry textbooks from the 2nd half of the 20th century (Table 2). The concept of the physical phenomenon is mentioned in the textbook from 1963 to point out the difference between these two kinds of processes. The comparison of physical and chemical processes was not used in following textbooks and appeared in the textbooks in 2010 again. There is written that the chemical processes are the changes, transformations, phenomena of the forming of new substances in textbook. These chemical changes, processes, phenomena are named the chemical reactions. They are proceeding in nature and many of them form the basis of the industrial production. The concepts such as the reactants (the substances which enter into the chemical reaction) and the products (the substances which forms during the chemical reaction) are introducing in textbooks. The concept of the chemical decomposition, the chemical combination and the chemical substitution also appear. The first efforts of symbolic writing of the chemical reactions (the chemical schemes, the chemical equations) are visible in the chemistry textbooks. The concept of thermochemistry in the chemical reaction content appears in the textbook from 1982, even it is not defined. The concepts: the system, part of the space with substance filing separated from surroundings of the real or imaginary walls, the molar heat of the reaction, and the symbols l (liquid), s (solid), g (gaseous), aq (aqueous) are mentioned in the chemical equations. The examples of the exothermic and endothermic reactions are mentioned, for example the process of photosynthesis, the breathing, the production of an iron and of the steel. The concept of chemical kinetics appears sequently in chemistry textbooks. The way of the products forming from the reactants is explained with the theory of the collision of particles. New concepts such as the collision effective orientation of particles are used. There are mentioned the factors affecting the chemical reaction rate: reactive surface area (grinding, milling), the concentration, the temperature effect (the freezing, the heating), catalyst (oil and natural gas processings, the production of methanol, nitric acid, sulphuric acid, the production of plastics). Biocatalysts (enzymes, hormones, vitamins) are mentioned there too. The first information about chemical equilibrium appears in 1963 in textbook. The course of the chemical reaction is not always unidirectional as the symbol of arrow shows. The reactions are running into reverse directions (the straight and the backward), the reactants are changing into the products and vice versa. The content of the chemical equilibrium in primary school textbooks later is not found.

Table 2: The key concepts and the connotations to the concept chemical reaction in the analysed chemistry textbooks from the 2nd half of the 20th century.

Textbook (author, title, year of publishing)	The key concepts and the connotations to the concept chemical reaction
Josef Trtílek, Rudolf Krsička, Josef Ondrášek Chemistry 8 1963	<ul style="list-style-type: none"> – the physical phenomena – new substances are not formed (the heating of the glass, the heating of the sulphur) – the chemical processes – new substances are formed (the heating of the sulphur in iron spoon, the heating of the sugar and the copper) – the chemical decomposition (mercury oxide, the decomposition of hydrogen peroxide with manganese dioxide) – the chemical substitution (sulphuric acid with zinc) – the chemical combination – the redox reactions; the reduction, the oxidation, the burning, the neutralization – the law of conservation of mass; the law of the stable combining ratio, valency, catalyst
mercury oxide → mercury + oxygen $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$	

Emil Adamkovič, Hofmannová,
Pumpř, Šramko, and Tomeček
Chemistry for the 2nd grade of
lower secondary education
1982

hydrogen + oxygen → water
(colourless (colourless (colourless
gas) gas) liquid)
 $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

- the chemical processes, the chemical reactions – different substances are formed
- the original chemical bonds cease to exist and new chemical bonds are forming
- the reactants, the products, the law of the conservation of mass
- chemical scheme (the reactants and the products are separated by interrupted arrow), the chemical equation
- the chemical decomposition, the chemical combination

Tibor Šramko et al.
Chemistry 8
1982

$\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g}); Q_m = -92.4 \text{ kJ mol}^{-1}$
exothermic reaction

$\text{C}_2\text{H}_5\text{OH} \xrightarrow[400^\circ\text{C}]{\text{ZnO, Fe}_2\text{O}_3} 4 \text{CH}_4 + 2 \text{CO} + \text{H}_2\text{O}$

- the chemical reactions as the changes of the chemical substances when one influences another and it causes the change into other substances
- the reactants, the products, the chemical scheme
- the exothermic and the endothermic reactions, molar heat, system, symbols l, s, g, aq
- the process of photosynthesis, the breathing, the production of the steel, iron, the burning
- the chemical reaction rate (the reaction of sodium with water, the reaction of calcium with water)
- the chemical reactions are running in reversible directions (the straight and the backward)
- the theory of the collision of particle: the collision, the effective collision, effective orientatin, sufficient energy
- the influence of the reactive surface area of the reactant, concentration and temperature on chemical reaction rate
- the concentration (the ratio of the mass amount of the dissolved substance and the volume of the solution)
- the catalysts (positive and negative katalysis, biocatalysts (enzymes, hormones, vitamis))
- the redox reactions (the oxidation, the reduction, electrolysis, galvanic cell)

Emil Adamkovič, Beneš, Pumpř,
Šramko, and Tomeček
Chemistry for the 2nd grade of
lower secondary education
1990

- the chemical reactions as the processes when new substances are formed from he certain substances
- the original chemical bonds cease to exist during the chemical reaction and new chemical bonds among atoms are forming
- the chemical reaction is written by the chemical scheme, the chemical equation
- the reactants, the products, the law of the conservation of mass
- the chemical combination (oxygen plus hydrogen, iron plus sulphur)
- the chemical decomposition (water)
- neutralization, precipitation reactions

Ernst Greb, Alfred Kemper,
Gottfried Quinzler
transl. Daniela Joniaková
Chemistry for lower school
education
1995

$\text{Fe} + \text{S} \rightarrow \text{FeS}$
iron + sulphur → ferrous
sulphide

- the chemical reactions as the processes when new substances are forming (copper roof is covering by green layer, the iron objects are covering by rust, the heating process)
- the reactants, the products
- the chemical equation, the chemical scheme
- burning (chemical reaction with oxygen, this reaction releases heat), forming of oxides
- the exothermic and the endothermic reactions
- activation energy – to initiate chemical reaction
- the chemical decomposition, the chemical combining
- the catalysts, inhibitors (positive and negative katalysis)
- the redox reactions, the oxidation, the reduction, electrolysis, neutralisation

Emil Adamkovič, Šimeková, and
Šramko
Chemistry 8
2000

- the chemical reactions as the processes when new substances are forming from the certain substances
- the reactants, the products, the scheme, the chemical equation
- the law of the conservation of mass
- the chemical decomposition, the chemical combining
- the neutralisation

Emil Adamkovič, Jela Šimeková
Chemistry 9
2001

- the chemical reactions as the processes when new substances are forming from the certain substances
- the reactants, the products, the chemical scheme
- the neutralization, the redox reactions (the oxidation, the reduction, oxidant, reductant, electrolysis, galvanic cell, accumulators, corrosion)
- the concentration
- the exothermic and the endothermic reactions (fuels, the breathing, the process of photosynthesis, the production of metal and their alloys)
- the chemical reaction rate as the time needed to run of the chemical reaction in seconds (the neutralization, the precipitation, the gas explosion), in days, weeks, years (the setting of mortar, the rusting of iron, the reducing of the ozon layer, the forming of the coal)
- the influence of the concentration (the burning of the fuel, the firefighting, the mulling of the metals), the temperature (increasing it about 10 °C, the speed of the reaction increases twice till forth times; the heating, the freezing), the reactive surface area of reactant (grinding, milling, stirring), the catalyst (enzymes, hormones, vitamins)

In the nowadays textbooks (Table 3) the curriculum about the chemical reactions is designated to lower secondary education. The teaching of this content is starting with the comparison of the physical and the chemical phenomena. The most important difference between them is that during the physical process the substances are not changing into other substances, but during the chemical process it is quite the other way around. The chemical processes are defined as the processes of the changing of the substances: from certain chemical substances (the reactants) there are forming other chemical substances (the products). There are several examples of the physical phenomena mentioned (paper cutting, ice melting) and also several examples of chemical phenomena are mentioned (the process of photosynthesis, the breathing, the burning, the rusting, the forming of calcium deposits, forming of caramel from sugar, the elimination of the calcium deposits). The chemical scheme is used for the putting down the course of the chemical reactions. The law of the conservation of mass is observed by the chemical reactions. The chemical combination and the chemical decomposition are mentioned as well. The energetical changes are introduced in the textbooks. There are some chemical reactions when the heat is getting loose (the exothermic reactions), other are connected with heat consuming (the endothermic reactions). The chemical reaction rate is associated with the concept of chemical reaction in the way, that the conception of chemical reaction rate we can obtain during the observation, as how quick the reactants in water solution are forming the solid product or how quick the coloration of reacting compounds is changing. The rate of the reaction course is determined by the time needed for changing/converting of the reactants into products. The examples of slow and quick chemical reactions are mentioned. The microscopic view on the chemical reactions is presented. It is not enough the encounter of the particles, they need to dispose of minimal energy and fitting orientation to the successful running of the chemical reaction. There are mentioned the factors affecting the chemical reaction rate (the number of reacting particles, the temperature, reactive surface area of the reactant, the catalyst) and the examples from the everyday life.

Table 3: The key concepts and the connotations to the concept of chemical reaction in the analysed chemistry textbooks using today.

Textbook (author, title, year of publishing)	The key concepts and the connotations to the concept of chemical reaction
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Helena Vicenová, Veronika Zvončková, Emil Adamkovič, Daniela Romanová
Chemistry for the 2nd grade of lower secondary education
2010

reactants → product

reactant + reactant → product

- the physical phenomena, the chemical processes, the chemical combining, the chemical decomposition
- the photosynthesis, the breathing, the burning, the rusting, forming and elimination of limescale, forming of caramel from sugar, the heating of blue vitriol, the reaction of the blue vitriol solution with the soda solution, reaction of hydrochloric acid with shell, reaction of the blue vitriol solution with the iron
- reactants, products, the chemical scheme, equation, law of conservation of mass
- energetic changes connected with chemical reactions (reaction of sodium with water, production of the iron, the burning lime)
- chemical reaction rate – time needed for changing of the reactants into products
- determination of the chemical reactions rate according to visual observation of reaction
- slow and quick chemical reactions (forming of the dripstones, the burning process, rusting, the damage of the limestone sculptures)
- collision of particles, efficient orientation of particles, minimal energy = activation energy
- amount of particles in reaction (firefighting, keeping the food in vacuum packings)
- temperature (keeping the food in fridge, pressure cooker, the heating)
- reactive surface area of the reactant (grinding, milling, stirring)
- catalyst: the production of sulphuric acid, ammonia; car, biocatalysts

Helena Vicenová
Chemistry for the 3rd grade of lower secondary education
2011

- chemical reactions are written by chemical equations (the meaning which substances are the reactants and the products, and particle number ratios),
- the reactants and products are marked by symbols and separated by arrow in the chemical equation
- the law of conservation of mass,
- neutralization, redox reactions (oxidation, reduction, burning, rusting)

Helena Vicenová, Mária Ganajová
Chemistry for the 2nd grade of
lower secondary education
2017

carbon + oxygen → carbon
dioxide

- the physical phenomena, the chemical processes, the chemical combining, the chemical decomposition
- the breathing, the photosynthesis, the heating of blue vitriol, the burning (ethanol, magnesium), reaction of the blue vitriol solution with the iron, the reaction of the blue vitriol solution with the soda solution, reaction of hydrochloric acid with shell
- reactants, products, the chemical scheme, equation, law of conservation of mass
- exothermic and endothermic reactions (reaction of sodium with water, production of the iron, the burning lime)
- chemical reaction rate – time needed for changing of the reactants into products,
- determination of the chemical reactions rate according to visual observation of reaction
- slow and quick chemical reactions (karstic processes, the decaying, acid rain effect on the buildings, the burning, decomposition of plastics)
- the collision of the particles, efficient orientation, minimal energy
- the effect of amount of particles in reaction, temperature, reactive surface area of the reactant, catalyst on chemical reaction rate
- praxis: firefighting, keeping the food in vacuum packings, in fridge, grinding, milling, stirring of solid reactants, usage of the catalysts (the production of sulphuric acid, in cars)
- biocatalysts in organisms, enzymes (production of beer, wine, cheese, spirits, penicillin)

Helena Vicenová
Chemistry for the 3rd grade of
lower secondary education
(textbook)
2018

hydrogen (H₂) + chlorine (Cl₂) →
hydrochloric acid (HCl)

- chemical reactions are written by chemical equations (the meaning which substances are the reactants and the products, and particle number ratios),
- the reactants and products are marked by symbols and separated by arrow in the chemical equation
- the law of conservation of mass,
- neutralization, redox reactions (oxidation, reduction, burning, rusting)

The definition of chemical reaction was shaped in the past and was forming to the contemporary version what is written down in the Figure 1.

Figure 1: The genesis of the definitions to the concept of chemical reaction in chemistry textbooks since 1869.

Nowadays there is generally accepted and in chemical sources presented the definition of the chemical reaction: Chemical reaction is a change in which one or more chemical elements or compounds (the reactants) form new compounds (the products). All reactions are to some extent reversible, the products can also react to give the original reactants. However, in many cases the extent of this back reaction is negligibly small, and the reaction is regarded as irreversible (Daintith, 2008). There were appeared a lot of definitions of the concept of Chemical reaction in textbooks. In the currently used textbook of chemistry is chemical reaction considered as a process during which the substances are changing: new chemical substances are forming from some chemical substances. The substances which are getting in and are reacting together are called reactants and substances which are a result of chemical reaction are called products. Therefore, during the chemical reaction the reactants are changing into products. The chemical reactions are written in the way of the chemical schemes – the chemical equations. The simple one is written with one reaction scheme and more complex are written with set of equations (Vicenová & Ganajová, 2017).

This specification is the result of analysis of the historical sources, of the phylogeny of key concept in connection with the scientific knowledge of that times and their reflection in the textbooks. Only this process could lead to precise the concept into contemporary perception and acceptance by the professionals and scientific experts. Several simple information and facts about the chemical reactions of chosen substances are in the textbooks for pupils of lower secondary education. The content proceeds from the concepts the compound, the element, the chemical combination, the chemical decomposition to help to define the concept of chemical reaction. It is very important to point out the condition of the forming, of the regulation of progress and of practical impact for everyday life. Then it is possible to explain the different kinds of the chemical reaction from many points of view (Dillinger et al., 1977).

Conclusions

The presented analysis of forming the concept of chemical reaction in Slovak pupils' conceptions in the diapason of past more than 100 years could help teacher to find a focus of his own model. The comparison of the object content in Slovak textbooks shows the reason of existence of two absolute different accesses to the depth and to the width of the curriculum related to the chemical reaction in the borders of more than 100 years lasting history. The conception from the 19th century is meaningful nowadays itself, because the need of teaching chemistry in connection of the everyday life is reasonable. There are not only expectant scientists and chemists, but most of the pupils will be in their future "the practical chemists", who will use their knowledge in the kitchen, in the bathroom etc. It is necessary for the school practice to handle safely the "traps of chemical phenomena" that surround us. On the other hand, we also need to prepare future scientists, who will make headway in the

human knowledge in that research field. That's why, the conception of the didactical scientism from the second half of 19th century has its application in modified and limited version.

According to the possibilities and the limits of the achievement of time period the textbooks also has been a part of process of developing. In the first half of the 20th century, the information were simplified, with black-white pictures (especially of chemical technologies) and schemes. Nowadays, many different visual elements are used, not only in the macroscopic level, but also in the submicroscopic and microscopic levels. Several textbooks contain the e-version on DVD with the visualisations and the simulations of the chemical reactions. The complexity of information has been gradually arising and according to the didactic reconstruction of teaching science it should be carefully chosen and selected in respect of pupils' and students' individual mental development and also the recent chemistry knowledge. We found out that in the oldier chemistry textbooks only the simple definition of chemical reaction was published with information about existing exo- and endothermic reactions. The chemical and physical processes were explained separately in chemistry and in physics. Nowadays, they are clearly differentiated also in topic of the chemical reaction. The chemical reaction content deepen gradually including the knowledge of thermochemistry, chemical reaction rate and chemical equilibrium. Pupils are able to understand the chemical reactions as the changes linked with the moving and interaction of valence electrons, connected with forming and destroying of the chemical bonds after learning about the chemical bonds and the electron theory (Dillinger et al., 1977). In the newer chemistry textbooks the aspects of chemical reaction rate were added to this field of research. There were mentioned the factors, which influence the rate of chemical reactions firstly without the principle how they works, later with the explanation which factor and how it affects the chemical reaction rate. Nowadays, the processes and the principles are better clearing up. The writting chemical reaction was firstly only verbal (as it is in the first acquaintance with the concept in the 7th grade pupils), later with the simply schemes, then there appeared symbolic scripts with punctuated arrows to recent written ways of chemical reactions. The chemical equation is a record of what happens in the chemical reaction (Green & Danji, 2001).

While analyzing the textbooks we found out, that not only in the older textbooks even in the new ones it is possible to read the claims and defintions that could be eventually the sources of key concept misconception of pupils. We should be carefull and critical to the information in textbooks too, because of possible misconceptions that will appear, if the information is not very well presented and understood. According to the textbook content analysis we found out that not only in the older textbooks the claim such as: While breathing we breath an oxygen in and a nitrogen returns back not used or the air consists of an oxygen (which is maintaining a fire) a nitrogen and a carbonic acid (what are not keeping a fire) appeared (Kožehuba, 1872), but in nowadays textbooks for lower secondary education the claim: The chemical reaction rate is appointed by the time needed for changing of the reactants into products (Vicenová & Ganajová, 2017) is mentioned, what is incorrect according to the physical units use for rate and of time. The several concepts appeared or got lost from the basic content, for example in the textbook from 2017 the concept of exothermic and endothermic reaction is mentioned, but several years earlier (2011) was not used. The concept of activation energy existed in the textbook published in 2011 and caused misunderstanding of this concept for several years in chemistry teaching, but in new one textbook (published in 2018) is not found.

Taber (2001), found out, that students may often have difficulty visualising molecular level processes and have very different mental image of the quantaction process and they thought that the reaction occurs so that the atoms present can get full shells. Many students do not differ between a chemical change and a change of state, which chemists call a "physical change" (Barker, 2000). Ahtee and Varjola (1998) dissolving and change of state were chemical reactions. The endeavour of science teacher is to respect teaching principles such as scientism and appropriateness in the whole context of understanding, but not to simplify the content into the level which could cause misunderstandings. That is the reason for being interested in historical point of view and for entreching key concepts from this scientific field into the conditions of pedagogical practice.

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Notes

- 1 "greencopper" = verdigris.

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