*Interdisciplinary*
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# MURPHY'S LAW IN CHEMISTRY

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**Abstract.** Not only has the Murphy's law acquired numerous supporters due to its populatity, but it has also expanded to all fields of human activity, from economy, through arts, to natural sciences. This work describes the creation and historical development of the Murphy's law, as well as a special movement within research-scientific Murphology, so-called *Murphy in chemistry*. Numerous "Murphian'' laws, postulates, rules and axioms directly derive from laboratory and research work in the field of chemistry. Moreover, there is a correspondence between certain chemistry contents (primary and secondary schoos) and rasearch Murphology, as well as its application within chemistry teaching. The use of the Murphy's law aims not only at bringing closer chemistry contents to students in an interesting way with the help of humour, but also at acquainting them with the issue of research, restoring the interest in chemistry and popularization of natural sciences.

*Keywords*: Murphy's law, Murphy in chemistry, primary and high school, chemistry teaching, students

## Introduction

Many have encountered in life the situations, which cannot be defined by some natural laws, in other words, for which no rational explanation exists. Why do they happen? What is the cause? Do we all succumb to their influence or not? For over a century people all over the world have tried to find the answers. A set of so-called, (un)natural laws, hypotheses, postulates, principles, regulations and rules are now collectively referred to as: Murphy's law (Bloch, 1998). According to the contemporary morphology,[1)] all laws can be classified into two groups in line with the wider social context:

a. Laws of the state, business and other interests of human groups,
b. Laws of Nature (Bloch, 1998).

The difference between murphology and scientific laws reflects in their relative validity. Unlike the natural laws, which define the physical causes, condition phenomena, predict the results of physical interactions, the (un)natural (Murphy laws) represent a generalized version and deal with the intent and purpose, with the factors which are not by nature physical the failure of scientific methods to explain the world of human society) (Bloch, 1998). Regardless of the fact that their position and importance for the society are not clearly defined (Bloch, 1998), there is no area of human activity (science, arts, sports and other), which is not encroached by the problematic of murphology.

The following question arises from the above statement: is it possible to apply the elements of the Murphy's law to the teaching of chemistry and its contents? Indeed, viewed from the point of education (chemistry teaching) and science (chemistry), they both represent the area and the subject and interest (research) of murphology.

**History of Murphy's law**

Prehistory of the development of the Murphy's law (Fig. 1) had begun long before the 1949[2)] and testing with the launching chair at the military base "*Edwards*" (Edwards Air Force Base Second Base) in California, USA[3)]. Research in the area of murphology confirmed the existence of a version of the law (the unnamed version of the law at the time) from 1877 pronounced by engineer, Stephen Goranson, a member of the American Society of dialectical (American Dialect Society, ADS), according to a report by Alfred Holt, also a member of ADS. In 1908 another version of the law appeared in the form of aphorism by the member of the ADS, Bill Mullins, which referred to the "*magic of the stage.*" [4)]

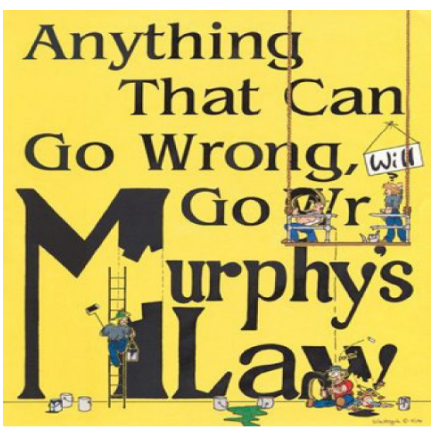


**Fig. 1**. Primary postulate of Murphy's law**:** "*Anything that can go wrong, will go wrong*"[5)]

In fact, modern murphology, as well as the law was named after the American military engineer, Aloyssious Edward Murphy, Jr.[6)] (1918-1990), who worked on the development[7)] and testing of catapulting-seat (*pilot-chair*) attached to missile-trolley (Figs. 2 and 3). In the beginning, engineers of Murphy's team experimented with a doll. Captain John Paul Stapp[8)] participated in certain tests[9)].

**Fig. 2.** Major, Aloyssious Edward Murphy, Jr.[10)]

**Fig. 3.** Edward Murphy, as a probe-pilot in the experimental-rocket-chair at the military base "Edwards" in the USA[11)]

The main cause of the emergence of the Murphy's law (originally Murphy-Murphy influence) was actually the mistake of one of the engineers, during the experiment with the chimpanzee. Electronic measurements showed a zero value, due to the incorrectly set (upside down) wire-sensors (measuring instruments). After the failure of probe-experiment, the disappointed Murphy[12)] uttered the famous sentence: "*If something can go wrong, it will*" ("*If there is any way to do it wrong, it will be done*" or "*Anything that can go wrong will go wrong*").[13)]

Thus because of mistakes (unintentional liberate, incurred from ignorance or accidental, originally murhologically) in connecting the wires and sensors by support-assistant-engineer and large numbers of failed tests, the (un)scientific law was developed, so called: applied or situational murphology (Bloch, 1998). The analogy with chemistry in the case of Murphy's law is more than obvious.

Experimental and research works in chemistry are full of similar examples and situations. From the many attempts to synthesize a new compound, uphold the conduct of the reaction (during syntheses), verify and prove the presence of the compound, derive new materials and drugs, the wrong formulated structures of compounds, etc. Therefore, it is possible to define chemistry in an unscientific way, from the perspective of murphology.

**Murphy's law**

It was only after the fifties of the 20$^{th}$ century that the Murphy's law experienced world popularity. First appearance of "bad luck"[14)] law was in the book from 1955: "*Men, Rockets and Space Rats*" by Lloyd Mallan.

Murphy's Law expanded quickly from the area of the aero-engineering to other technical areas, entering general technical culture. Variations of Murphy's Law become part of the modern slang and the "*spirit*" of the laws makes the basic principle: "*the negative things happen unexpectedly.*"[15)]

In everyday use, appears the form: "*If something can go wrong, it will go*". Other variants are known under different names (*Finagle-Barrels law* or *the Law of Britain*). There are other, popular examples which are often used to point out the inevitability of the bad luck outcome: *Why does toasted bread land buttered-side-down*?[15)]

Murphy's Law is a form of philosophy of life. Taking a defensive attitude in life means prediction of possibility that things may go wrong, either in the engineering design, love, traveling by bus, car and plane, carrying the watermelons from the market, during the operation, fixing the satellite dishes and other bizarre situations. Some people indicate that it could be good to take certain precautions in life, while others have a specific religious approach, which is a wrong interpretation of Murphy law (*Murphy's religion*).[15)]

It should be noted that Murphy's Law is general (nonscientific) and universal (analogous to natural sciences). It is always valid and everyone can be assured of its accuracy, depending on, how much they are potential Murphiest.[16)]

Today, there are numerous books[17)] written on the subject of Murphy's Law, for scientific and other fields of human activity (Bloch, 1998). Murphy's law has acquired not only great popularity, but it has also been divided into separate sections and directions, such as: situational, work, office, research, government, economic, academic, medical, sports, traffic, purchasing and social murphology.

The topic of the morphology of research refers to problems in the experimental (practical) and research-theoretical works, encountered equally by: scientists, teachers (professors and teachers), students and pupils.

A special sub-group of the murphology of research represents murphology in chemistry (Fig. 4), better known under the name: *Murphy in Chemistry* (Bloch, 1998).

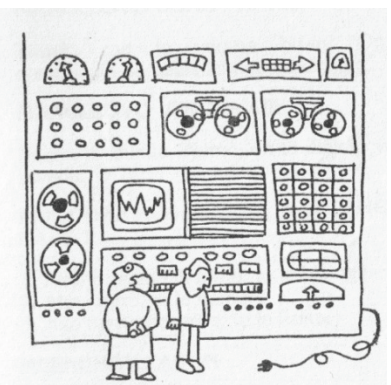

**Fig. 4.** Murphology in Science[18)]

**Murphy in Chemistry**

There is no chemist-experimenter, a teacher, professor, student, who has not had a sort of "*close*" encounter with Murphy's Law, during the work in laboratory, at the lectures, exams or studying.

For each of these situations there are certain laws, principles or postulates which occurred as a result of interaction of Murphy's unscientific elements and logical-rational chemistry. Each of them is named as the person, who defined the certain law or postulate in accordance with tradition of Murphy and naming according to the rules of scientific terminology.

Although Murphy's Law, by nature an unscientific law, is opposed to (scientific) chemistry (Bloch, 1998), its application in teaching of chemistry is not strictly didactical or methodical, from theoretical point of view (Halaši & Kesler, 1976). However, the requirements, dictated by the modern teaching of chemistry (*new thinking in chemistry*) (Woest, 1997), interests of students, their psychological and emotional state (Levine, 2002), influence of media and modern technical and technological developments (Stojkovic & Kostic, 2009; Stojković, 2010; Kostic et al., 2008), allow the application of any methods, procedures and ideas in order to popularize natural sciences (chemistry). This is certainly related to Murphy's Law as well. Thus, Murphy in Chemistry has a special role of activator and motivator of the student interests, since it is based on the comic (funny) elements, which derive from the theory and practice, while a few teaching contents (7$^{th}$ and 8$^{th}$ grade) in chemistry match with certain areas (experimental and research work) of Murphy's law.

Chemistry teaching is rich with different examples (from work in the laboratory to the explanation of certain phenomena), on which the Murphy's Law can be applied. Therefore, they is good to quote (indicate the representative examples) in the teaching of chemistry, whenever there is a possibility for that.

Here are certain examples of laws, postulates: principles, rules, instructions and axioms of the researching murphology, the validity of which is confirmed by examples in educational practice and theory:

**First law of the laboratory**

*Hot test tube looks exactly like the cold one* (Bloch, 1998).

When explaing the basic rules of the the laboratory work (Мандић et al., 2005) it could be good to quote the fist law of the lab. The hot test tube does differ from the cold one, unless confirmed by the sense of touch, which of course is not recommended! Gesticulation (mime) by the teachers and specifying of examples from own experiences contribute to the visualization of the situation by students (Levine, 2002). Although students (7$^{th}$ grade) have almost no experience with the the laboratory work, this example is very funny for them. A situation in which a person has a test tube "glued" to their hand is unthinkable for them.

**Basic rules for laboratory workers**

*If you do not know what you are doing, do it with style* (Bloch, 1998).

This rule describes situations encountered and experienced equally by: chemists,

teachers and students. There is not chemist who, during the conduct of an experiment, because of the complexity, the lab apparatus, improvisation, conditions of work and the failure of synthesis, does not confirm this rule. Students must always be acquainted with the fact that work in the laboratory is not easy, that many reactions and experiments must be repeated several times to obtain certain yield and the needed substance. Nevertheless, the attained experience can only contribute to further development and improvement of methods and procedures ("*No pain, no science*").

**Finagle's eighth rule**

*Teamwork is very important. It allows throwing the blame on other* (Bloch, 1998).

When working in teams, there appear problems in interpretation of data or presentation of the conclusion, which results with conflicts, harass and small quarrels among the students. The rule of teamwork shows that whenever there is possibility one can always blame another member of the team for the failure. In fact, the rule expresses the psychological state of the individual in the group and can be related to personal abilities of students. Therefore, it is necessary to explain that teamwork is essential for success in scientific research, especially if it is important for scientific projects, where cooperation has great importance as well as the exchange of ideas. Of course, to error is human.

**Finagle's belief**

*Science is true. Do not let facts mislead you* (Bloch, 1998).

In terms of the relation between science and facts, the latter must always be given priority before making conclusions. Acceptance of merely certain facts and opinions would lead to the existence of a unilateral vision (*pattern-exemplar*) of science. For that reason, during the teaching process, it is essential that students develop and attend the logical, rational and critical thinking and freedom of expression and presentation of ideas.

**Special guide to the modern science**

*1. If it is green or kicking, it is biology.*

*2. If it smells bad, it is chemistry.*

*3. If it does not work, it is physics* (Bloch, 1998).

Special guides represent three definitions (very popular) of the natural sciences. Unscientific definition of these sciences for its simplicities and contents are much closer to students' interests, needs and conceptions, rather the classic definition of biology, chemistry and physics (because of the use of foreign terms, memorization of long sentences, incorrect answers und definitions). Recognition of the unscientific (according to Murphy in Chemistry) definition of natural science, apart from scientific definition, leads to outsourcing, simplification and approximation of the teaching content in chemistry, which students consider difficult to understand; it also increases the interest, motiva-

tion and reduces the difference in terms of interests and needs (closer to real life and practical application). The unscientific definitions can help or remind the students, if they do not know the other (scientific) definition. A little joke at the expense of science does not hurt anyone!

**Velilind's laws of experiments**

*1. If repeated experiments can give different results, test only once.*

*2. If an experimental graphic is to be a straight line, obtain data for only two points* (Bloch, 1998).

**Rule of the ruler**

*There is no such a thing such a thing as a straight line* (Bloch, 1998).

Two very important rules of laboratory work according to murphology, resulting from practice. An excellent example, good to quote when performing a variety of demonstration experiments in the school or experiments performed by students (Halaši & Kesler, 1976; Мандић et al., 2005; Herak, 1979).

Many a time during the conduct of experiments do matching results appear which leads to repeating the experiment? This situation is exceptionally difficult, especially if there is a problem with the time and conditions of conducting the experiments. Therefore, one test is (in Murphy's case) sufficient. The graphic presentation of results in the form of experimental straight lines is an ideal case. Since the results depend on the conditions of conducting the experiment (which can be unpredictable), drawing in straight line (not always a straight line) is just approaching the ideal case. On the other hand, these two laws are the guide for the successful performance of experiments according to Murphy (conditions of ideal experiments).

**Lerman's law of technology**

*Any technical problem can be solved with sufficient amount of enough money and time* (Bloch, 1998).

*Lerman's message: you are never given enough money or time* (Bloch, 1998).

Perpetual problem which accompanies any research and scientific work. The validity of the Law of Technology is confirmed by the financial resources of our schools. When you plan planning to do the experiment (demonstration) there will never be enough time, because if you are using the "*stick*" and "*rope*" one the preparation, you have already spent most of the time for a performance. As for money, it is always deficient.

**Thumb's first postulate**

*It is better to solve the problem with a rough approximation and find out the truth (-/ +10%), than require the exact answers and not know the truth* (Bloch, 1998).

This is a good example in order for you to be able to explain the problems in chemistry calculations. Solving mathematical problems (stoichiometry, calculating the number of moles and particles using proportions or the use of formulae) (Мандић et al., 2005) in chemistry is not a favorite subject for students. In addition to chemistry, mathematics does not belong to a group of favorite subjects (Woest, 1997). The combination of mathematics and stoichiometry of chemical reactions further complicates calculation. Truthfulness of the postulates corresponds to the example of calculations in chemistry. Seek for truth through knowledge of the chemical stoichiometry (importance of knowing the procedures of stoichiometry calculation and equalization of chemical reactions in relation to calculation).

**Thumb's second postulate**

*Easily understandable, work acceptable untruthfulness is more useful than complicating and incomprehensible truth* (Bloch, 1998).

It is often necessary to apply the postulate (Thumb's) of untruthfulness faultiness of the scientific truth. This leads to deviation from the basic didactic and methodological principles. Many students, because of the complexity of certain items from chemistry, do not understand the theory, principles and terminology. Therefore, it is sometimes necessary to deviate from scientific truths in order to explain them. For example, the term ozone hole is taken literally by most students literally; it is the "*hole*" in the atmosphere. This represents an example of simplified explanations and has analogy with an example from life. For a student the greenhouse represents a "*big glass*" like a greenhouse (farm), which hangs in the atmosphere and reflects Sun's rays. These examples directly derive from life experience.

**Mann's law (general)**

*If a scientist discovers a bombast fact, it becomes central to his theory*. *Moral: His theory will, in turn, become central to the whole scientific thought* (Bloch, 1998).

There are many examples from science which confirm that the discoveries and inventions of scientists really can sometimes be a brake to further progress of a particular scientific discipline and science itself. As part of teaching chemistry to elementary school ($7^{th}$ and $8^{th}$ grade) there are teaching units which include the topics related to important discoveries and scientists' research (important for the development of chemistry) (Llansana, 2004). However, those unites are not explained in detail. When presenting the teaching content from this topic, apart from providing examples, it is also necessary to explain to students which theories had a significant impact on the development of scientific thought and had been valid and central to science, before another theory. For example, effluence of Dalton's atom theory as a new and central in the 19th century, regardless of theory which is the very old, 2500 years, which comes from ancient

Greek, philosopher Leucippus (Leucippus, 5th century BC) and Democritus (Democritus, 460-370 BC) (*atomos-smallest*, *indivisible particle*) (Мандић et al., 2005). Then, experiments with the breathing of living beings, Anton Lavoisier (Antoine-Laurent de Lavoisier, 1743-1794) together with the famous mathematician and astronomer Pierre Laplace (Pierre-Simon, Marquis de Laplace, 1749-1827), which confirmed that breathing process is combustion, which, as Lavoisier claimed, occurred in the lungs, not in the tissues. In fact, the life of the famous scientist completed according to the "screenplay" arising from the very Murphy's Law: he was under false charges and was executed by the Revolutionary government of France for tax evasion and treason.[19] In life and in science, one needs to be lucky.

**Conclusion**

Murphy Law (Murphy in Chemistry) in teaching chemistry attempts to bring closer the issues of scientific and experimental research to students, simply present the theoretical content, through humor (comic situations from the life of famous scientists and science), further motivate, attract, bring closer and simplify contents adapting them to the interest of students.

Viewed from the perspective of education in teaching chemistry (Halaši & Kesler, 1976) quoting the principles and theories of the Murphy's Law encourages creativity and imagination of students. Alternately, Murphy (laws, principles, theories, etc.) in chemistry are more accessible and simpler, closer to the interests of students compared with complex theoretical elements (terminology, definitions, terms, symbols). In this, one must be certain not to digress from scientific truth when teaching of chemistry, but must ensure, that chemistry teaching digress from scientific truth. As opposed to misunderstanding of complex theoretical elements in chemistry by students, the introduction of Murphy in chemistry would certainly have a positive impact on promoting science and return of interest in the contents of chemistry. Although the Murphy's Law is unscientific.by its structure, what interest's students most are its entertaining and humorous elements.

NOTES

1. Murphology is a (un) scientific discipline, representing a systematization of new laws and postulates not applicable in a practical sense, (non-experimental), but which derive directly from life experience. Bloch, A. (1998). *Murphyjev zakon, još razloga zašto stvari idu naopako*!Priredili: Dragan Milosavljević, Slobodan Marinković, Beograd: Prozaik.
2. The modern form of the Murphy`s law appeared as the epigraph to the mountaineering book (not before 1952) by Jack Sack. Murphy Law, http://en.wikipedia.org/wiki/Murphy_law
3. According to the English version of Wikipedia, the origin of Murphy' Law cannot be directly related to the numerous experiments conducted by the military engineer Edward Murphy in the known American Edwards Military Base. Murphy Law, http://en.wikipedia.org/wiki/Murphy_law

**4.** The expression "*magic of the stage*" refers to various magic tricks performed in theatres and circus performances in America and Europe during 18th and at the beginning of 19th centuries. Murphy Law, http://en.wikipedia.org/wiki/Murphy_law

5. Source (Fig. 1): Murphy's Laws in the Stock Markets, www.greekshares.com/murphy.php

6. Murphy was born in Panama (Panama Canal Zone) in an American family of Irish descent, and was the oldest of five children. He graduated from high school in New Jersey (New Jersey) and the Military Academy in West Point (West Point). In 1940 he participated in the Second World War as a pilot at the Asian front (India, Burma and China). From 1947 he worked at the Air Force Institute of Technology (United States Air Force Institute of Technology), as an officer at the Center of Wright Aircraft, Wright-Patterson (Wright-Patterson Air Force Base). In 1952 he left the army and participated in testing missiles in accelerator at the Military Base Holloman (Holloman Air Force Base). He also worked on the system for the rescue of many experimental aircraft (F-4 Phantom II, the XB-70 Valkyrie, SR-71 Blackbird, B-1 Lancer and X-15 rocket plane), and life support systems, space project "Apollo" (Project Apollo). His career ended with the development of computer operating system for Apache helicopters (Apache helicopter), http://en.wikipedia.org/wiki/Edward_A._Murphy

7. The project called "MX981" at the military base Edwards, where the group of scientists, during the war performed various experiments. In 1949 he started the research project carried out in order to investigate the ability of the human body to withstand significant acceleration (G force). Murphy`s Law Sites, All the laws of Murphy in one place, www.murphys laws.com/murphy/murphy-true.html

8. According to many Murphologists, Captain John Paul Stapp was the first person (engineers), who told the statement: "*If it can happen, it will happen*". Murphy Law, http://en.wikipedia.org/wiki/Murphy_law

9. The book by Nick T. Spark, A History of Murphy''s Law (2006) based on a story by (the author's neighbor) the son of the engineer David Hill Sr., who had worked with Edward Murphy at the Edwards Military Base. The Fastest Man on Earth (Part 1 of 4), Why Everything You Know About Murphy's Law is Wrong, http://improbable.com/airchives/paperair/volume9/v9i5/murphy/murphy1.html

10. Source (Fig. 2): Origin of 'Murphy's Law', www.unsv.com/voanews/wordmaster / scripts/2003/10/30/

11. Source (Fig. 3): "Dig For Victory"-The Intranet Portal Guide, http://www.viney.com/DFV/intranet_portal_guide/during/business_change_management.html

**12.** Many admirers and followers of the Murphy's law believe that the creator of murphology tragically died as a victim of his own laws (Murphy vs. Murphy). According to them, one night Murphy was left without fuel in the car on the road. He went to a gas station, and a car hit him, because it was on the wrong side of the road. An Englishman was driving the car. Of course, is it about a kind of joke at the expense of Irish descent of Murphy. http://www.mprestige.net/eprestige/cc/cae/caetext/reading4.htm and http://asmaiftikhar.hubpages.com/hub/PRACTICAL-EXAMPLES-OF-LAW-OF-MURPHY

13. There are several more possible versions of the original Murphy's law. According to the

testimony of another supporting engineer Murphy was criticizing the engineer-assistant, after the failure of the trial-experiment, with the following words: "If that guy can spoil anything, he will". This statement was later used by engineers in the following (modified) form: "If it can happen, it will happen". By the third version, according to the stories of Murphy`s son, it says: "If a job can be done in two or more ways, and only one leads to destruction, it will be done just so". Murphy Law, http://en.wikipedia.org/wiki/Murphy_law

14. According to many, the Murphy's Law is a sequence of bad events, bad luck.
15. Murphy's Law was inspiring (for all areas of human activity), so that, under the influence of "Murphian laws and postulates", many have tried to write (define) their own laws resulting from their lives, work and personal experience. Murphy Law, http://en.wikipedia.org/wiki/Murphy_law
16. Veracity of the first law of traffic, Oliver`s law of the Locations: "No matter where you are going, you are there", was experienced by the author of the article himself. Starting from Jena (Jena) to Zurich (Zürich), and accompanied with a series of "bad lack" situations, the journey increased from 8 to 11 hours. All because of an "inexplicable" delay of 15 minutes at the departure station, the author missed the train from Nurnberg for Stuttgart. On the way to Stuttgart, because of the fire caused by combustion of wood girder rails, the train in which the author was could not move for 70 minutes. Because of this delay there was an additional delay of the train from Stuttgart to Zurich of 60 minutes. Finally, the trip ended with a three hour delay. Oliver's law of the Locations seemed inspiring to write an article about Murphy's law in chemistry.
17. They are: Arthur Bloch, Murphy's Law, 1977; Arthur Bloch, Murphy's Law, the second book, 1980, and two specialized books: Murphy's Law, Doctor: Make perfect abuse; Lawyers: Warp rights in the legal profession!.
18. Source (Fig. 4): Bloch, A. (1998). *Murphyjev zakon, još razloga zašto stvari idu naopako*!Priredili: Dragan Milosavljević, Slobodan Marinković, Beograd: Prozaik.
19. The Revolutionary government of France could not accuse Lavoisier of tax evasion; they accused him of trying to poison the air in Paris raising a wall, as well as discovered and capturing a so-called: "*fire-element*" and proving it to the Academy of Sciences. In fact, it was a plot constructed by a political opponent of Lavoisier, Mare. During the trial against Lavoisier and other 27 people, the judge said to the lawyer of Lavoisier the following sentence: "*The Republic has no need for scientists, justice has to be satisfied*". On 8th May 1794, Lavoisier was executed on a guillotine. A later, repeated investigation proved that all of the executed were innocent. Vićanović-Draškić, I. (4.1.2002). *Šta će Republici naučnici?* Politikin Zabavnik, Godina LXIV, broj 2604, 17

REFERENCES

Bloch, A. (1998). *Murphyjev zakon, još razloga zašto stvari idu naopako*. Beograd: Prozaik.

Halaši, R. & Kesler, M. (1976). *Metodike nastave hemije i demonstracioni ogledi.* Beograd: Naučna knjiga.

Herak, J. (1979). *Didaktički temelji početne nastave kemije.* Zagreb: Školska knjiga.
Kostic, D.A., Mitic, S.S., Zarubica, A.R., Gosnjic, A. & Stojkovic, M. (2008). Comparing the computer supported approach versus traditional „teacher-student" one. *Chem. Educ. J. 11*(2), No. 21, 10-22.
Levine, M. (2002). *A mind at the time*. New York: Simon & Schuter.
Llansana, J. (2004). *Školski atlas fizike i hemije.* Beograd: Kreativni centar.
Stojkovic, M.D. & Kostic, D.A. (2009). Utilization of contemporary tools in teaching chemistry-computers, computer programs and Internet. *Chemistry 18*, E108-E118.
Stojković, M.D. (2010). Study of the structure and polarity of amino acids in high-school teaching with the help of computer programs. *Chemistry 19*, E129-E141.
Woest, V. (1997). *Den Chemieuntericht neu denken: Anregungen für eine zeitgemässe Gestaltung.* Darmstadt: Leuchtturm-Verlag.
Мандић, Љ., Королија, Ј. & Даниловић, Д. (2005). *Хемија за 7. разред основне школе.* Београд: Завод за уџбенике и наставна средства.

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