Chemical education research paper

Why Has the Bohr-Sommerfeld Model of the Atom Been Ignoredby General Chemistry Textbooks?

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Received: 06-06-2011

Abstract

Bohr's model of the atom is considered to be important by general chemistry textbooks. A major shortcoming of this model was that it could not explain the spectra of atoms containing more than one electron. In order to increase the explanatory power of the model, Sommerfeld hypothesized the existence of elliptical orbits. This study has the following objectives: 1) Formulation of criteria based on a history and philosophy of science framework; and 2) Evaluation of university-level general chemistry textbooks based on the criteria, published in Italy and U.S.A. Presentation of a textbook was considered to be "satisfactory" if it included a description of the Bohr-Sommerfeld model along with diagrams of the elliptical orbits. Of the 28 textbooks published in Italy that were analyzed, only five were classified as "satisfactory". Of the 46 textbooks published in U.S.A., only three were classified as "satisfactory". This study has the following educational implications: a) Sommerfeld's innovation (auxiliary hypothesis) by introducing elliptical orbits, helped to restore the viability of Bohr's model; b) Bohr-Sommerfeld's model went no further than the alkali metals, which led scientists to look for other models; c) This clearly shows that scientific models are tentative in nature; d) Textbook authors and chemistry teachers do not consider the tentative nature of scientific knowledge to be important; e) Inclusion of the Bohr-Sommerfeld model in textbooks can help our students to understand how science progresses.

Keywords: Bohr, Sommerfeld, General chemistry textbooks, Tentative nature of science

1. Introduction

Starting from the late nineteenth century atomic models changed in quick succession, that is from Thomson[1] to Rutherford[2] to Bohr[3]. Most high school and university-level introductory general chemistry textbooks ignore the underlying pattern of these changes, namely the tentative nature of scientific theories. According to Niaz[4], "Most textbooks ignore the fact that progress in science evolves through competition between rival and conflicting frameworks, and the work of Thomson, Rutherford and Bohr is particularly illustrative of this tentative nature of science" (p. 548). More recently, Niaz and Cardellini[5] have argued that:

a) Bohr's model of the atom provided an explanation of the paradoxical stability of the Rutherford model and spectra of hydrogen like ions;
b) Despite its popularity and novelty, Bohr's model only explained the stability, ionization energy and the spectra of ions possessing a single electron (H^+, Li^{2+}, Be^{3+});
c) Sommerfeld's[6] innovation consisted in treating the problem relativistically by introducing elliptical orbits, in which the electrons penetrated the region of internal electrons. Thus, the highly elliptical orbits would have additional stability;
d) Bohr-Sommerfeld model of the atom was widely accepted by the scientific community as an alternative to Bohr's model. For example, Paschen's measurement of the helium spectrum was in agreement with Sommerfeld's prediction;
e) The Bohr-Sommerfeld model went no further than the alkali metals, which led scientists to look for other models. These difficulties were resolved by Pauli's exclusion principle and other developments;

f) From a history and philosophy of science perspective, Bohr-Sommerfeld model can be interpreted as an "auxiliary hypothesis"[7], in order to restore the viability of Bohr's model to a certain degree;
g) This journey in which we were accompanied by Thomson, Rutherford, Bohr and Sommerfeld, clearly shows the tentative nature of scientific theories.

Research in science educations has recognized the tentative nature of scientific theories as an important aspect of progress in science and nature of science.[8–13]

Based on these considerations, this study has the following objectives:

1. Formulation of criteria based on a history and philosophy of science framework.
2. Evaluation of university-level general chemistry textbooks published in Italy and U.S.A., based on the formulated criteria.

2. Criteria for Evaluation of General Chemistry Textbooks

In the previous section we showed that although general chemistry textbooks do present Bohr's model of the atom, these presentations generally do not refer to its deficiencies. History of science shows that these deficiencies were important and led to the postulation of another model, namely the Bohr-Sommerfeld model. Based on these considerations it is plausible to suggest that in order to facilitate a better understanding of how scientific models develop and the tentative nature of scientific knowledge, it is important for the textbooks to include the following aspects:

1. Bohr's model of the atom could only explain the spectra of hydrogen-like ions, based on circular orbits.
2. Bohr-Sommerfeld model of the atom based on elliptical orbits, not only specified the shape of the orbit, its orientation in space, but also provided additional stability.

Based on the criteria developed in this study, general chemistry textbooks were classified in the following categories:

Satisfactory (S): Presentation of a textbook was considered to be "satisfactory" if it included a description of the Bohr-Sommerfeld model along with diagrams of the elliptical orbits.

Mention (M): Presentation of a textbook was considered to be "mention" if it made a simple mention of the model and/or elliptical orbits with no diagrams or details. If a textbook mentioned the model and/or elliptical orbit, but not Sommerfeld, it was still classified as (M).

No-mention (N): Textbooks in this category made "no-mention" to the Bohr-Sommerfeld model or elliptical orbits.

2. 1. Reliability of Application of the Criteria

Based on the history and philosophy of science framework, both authors first analyzed two textbooks published in Italy and two in U.S.A. All differences were resolved by discussion and a consensus was achieved. Later the first author analyzed all textbooks published in U.S.A., and the second author analyzed all textbooks published in Italy. At this stage it is important to mention as to why we decided to analyze these textbooks. Textbooks published in U.S.A. are also used in other English speaking countries and also as translations in Spanish, Portuguese, Turkish, Greek and Italian. Despite the widespread use of textbooks published in U.S.A., we also wanted to compare these textbooks with those published in another country (Italy). Furthermore, all Italian textbooks included in this study were not translations of textbooks published in U.S.A.

2. 2. Criteria for the Selection of General Chemistry Textbooks

a) As the historical events relating to the Bohr-Sommerfeld model occurred in the period 1915–1930, we decided to analyze textbooks starting from the 1960s. It was expected that the textbooks would include the historical details after about 30 years.
b) Based on consultations with colleagues we looked for textbooks in our university and nearby libraries. Almost all textbooks used in this study are available in university libraries in Italy and the U.S.A.
c) Selection of textbooks from different time periods, including recent ones.
d) Inclusion of textbooks that have published various editions, which shows their acceptance by the science education community, both in Italy and the U.S.A. These textbooks are widely used in both countries.
e) Consultations with colleagues in different parts of the world revealed that various textbooks published in U.S.A. (especially those with various editions) selected for this study are used as translations (among other languages: Spanish, Portuguese, Italian, Greek and Turkish).

3. Evaluation of General Chemistry Textbooks: Results and Discussion

3. 1. Textbooks Published in Italy

Appendix 1 presents a complete list of the 28 general chemistry textbooks published in Italy. Of these textbooks (see Table 1) five were classified as satisfactory (S) and seven as mention (M).

Following are examples of two textbooks that were classified as satisfactory (S):

Table 1. Evaluation of Italian General Chemistry Textbooks (n = 12)

No.	Textbook	S	M
1.	Bertani, Clemente, Depaoli, Di Bernardo et al. (2001)		X
2.	Bertani, Clemente, Depaoli, Di Bernardo et al. (2006)		X
3.	Chiorboli (1980)	X	
4.	Dapporto and Spinicci (1993)	X	
5.	Deganello and Maggio (1982)		X
6.	Lorenzelli (1969)	X	
7.	Nardelli (1991)		X
8.	Nobile and Mastrorilli (2006)	X	
9.	Schiavello and Palmisano (2006)		X
10.	Silvestroni (1997)		X
11.	Spinicci (2004)	X	
12.	Zanello, Mangani and Valensin (2001)		X

Notes:
1. Textbooks included in this table were classified as S or M.
2. S = Satisfactory. These textbooks included a description of the Bohr-Sommerfeld model along with diagrams of the elliptical orbits.
3. M = Mention. These textbooks made a simple mention of the model and/or elliptical orbits. Some of these textbooks did not mention Sommerfeld.
4. Of all the Italian textbooks included in Appendix 1 (n = 28), only those reported here were classified as S or M. All the other textbooks made No-mention (N) of the Bohr-Sommerfeld model.

Presentation of Lorenzelli (1969):

The title of chapter 3 in this textbook is: "The Bohr-Sommerfeld atom". In a section entitled: "The secondary quantum number *l* and the Sommerfeld's atom" it stated:

> Sommerfeld, in 1916 made a first important improvement of Bohr's model, by introducing a second quantum number based on the previous general considerations [the analogy with the planets' motion]. If the orbits are elliptical, the position of the electron in the orbital plane is defined by two periodic quantizable variables, the radius vector *r* and the angle φ (fig. 3). A double quantization carries then along to define two quantum numbers .... (p. 27).

Presentation of Dapporto and Spinicci (1993)

In a section entitled: "Electronic structure of atoms" it stated:

> The fine structure of the hydrogen atom spectrum induced Sommerfeld to assume some modifications to the Bohr's atomic theory. In particular, if every line is constituted by more lines and if it is true that every line derives from the leap between two energetic levels, it must be concluded that every energetic level consists of one or more sublevels (p. 23). [Note: On page 24, authors stated, "Quantum number *l* related to elliptical orbits …" and on page 23 provided a diagram (Figure 1.9) of elliptical orbits, quite similar to the one presented in this manuscript].

These satisfactory (S) presentations explicitly refer to the problems associated with Bohr's model and hence the need for improvement. Besides the recognition of difficulties these textbooks go beyond by suggesting an alternative provided by Sommerfeld's elliptical orbits that explained the comlexity of the spectra and hence stability.

Following are two examples of textbooks that were classified as mention (M):

Presentation of Bertani et al. (2001)

In a section entitled: "The atom's structure according to Bohr" it stated:

> Bohr's theory was later improved by Arnold Sommerfeld (1868–1951) introducing elliptical orbits, for explaining details of the emission spectra of atoms of elements different from hydrogen (p. 47).

Presentation of Zanello et al. (2001)

In a section entitled: "The atom's structure according to Bohr" it stated:

> [Bohr's atom] does not explain why in a magnetic field, the hydrogen spectrum is more complex (*Zeeman effect*). The German, Arnold Sommerfeld (1868–1951) remedied this by assuming that in such conditions the electronic orbits are not *circular*, but *elliptical* (p. 69).

Textbooks classified as mention (M) do refer to the problems with Bohr's model and Sommerfeld's elliptical orbits. However, in comparison to textbooks classified as satisfactory (S), these did not provide diagrams of the elliptical orbits. Overall, textbooks that were classified as satisfactory (S) or mention (M) provided a much better picture of scientific progress as compared to the 16 that were classified as no-mention (N).

3. 2. Textbooks Published in U.S.A.

Appendix 2 provides a complete list of the 46 general chemistry textbook published in U.S.A. Of these textbooks (see Table 2) three were classified as satisfactory (S) and three as mention (M).

Table 2. Evaluation of U.S.A. General Chemistry Textbooks (n = 6).

No.	Textbook	S	M
1.	Dickerson, Gray, Darensbourg, Darensbourg (1984)	X	
2.	Mahan, Myers (1990)		X
3.	Pauling (1970)	X	
4.	Whitten, Davis, Peck (1998)		X
5.	Wolfe (1988)	X	
6.	Zumdahl (1993)		X

Notes:
1. Textbooks included in this table were classified as S or M.
2. S = Satisfactory. These textbooks included a description of the Bohr-Sommerfeld model along with diagrams of the elliptical orbits.
3. M = Mention. These textbooks made a simple mention of the model and/or elliptical orbits. Some of these textbooks did not mention Sommerfeld.
4. Of all the U.S.A., textbooks included in Appendix 2 (n = 46), only those reported here were classified as S or M. All the other textbooks made No-mention (N) of the Bohr-Sommerfeld model.

Following are two examples of textbooks that were classified as satisfactory (S):

Presentation of Pauling (1970)

> In 1915 the German physicist Arnold Sommerfeld extended Bohr's treatment to include certain elliptical orbits. In his treatment he introduced three quantum numbers to describe the orbit of the electron. The total quantum number *n*, giving the energy of the atom (Equation 5–4), also determined the semimajor axis of the ellipse as n^2a_0. The angular-momentum quantum number *k*, equal to or smaller than *n,* determined the semiminor axis as nka_0. The third quantum number *m*, described the component of angular momentum along the direction of an applied magnetic field (see Section 3–8). Some of the Sommerfeld elliptical orbits are shown in Figure 5–2. The Bohr-Sommerfeld description of electrons in atoms has now been superseded by the wave-mechanical description, which, however retains some of the features of this earlier model (p. 115).

Presentation of Dickerson et al. (1984)

This textbook presents the Bohr-Sommerfeld model of the atom in a section entitled: "Need for a better theory" and following are some of the excerpts of this presentation:

> Arnold Sommerfeld (1868–1951) proposed an ingenious way of saving the Bohr theory. He suggested that orbits might be elliptical as well as circular. Furthermore, he explained the differences in stability of levels with the same principal quantum number, *n*, in terms of the ability of the highly elliptical orbits to bring the electron closer to the nucleus (Figure 7–15). For a point nucleus of charge +1 in hydrogen, the energies of all levels with the same *n* would be identical. But for a nucleus of +3 screened by an inner shell of two electrons in Li, an electron in an outer circular orbit would experience a net attraction of +1, whereas one in a highly elliptical orbit would penetrate the screening shell and feel a charge approaching +3 for part of its traverse. Thus, the highly elliptical orbits would have the additional stability (pp. 269–271).

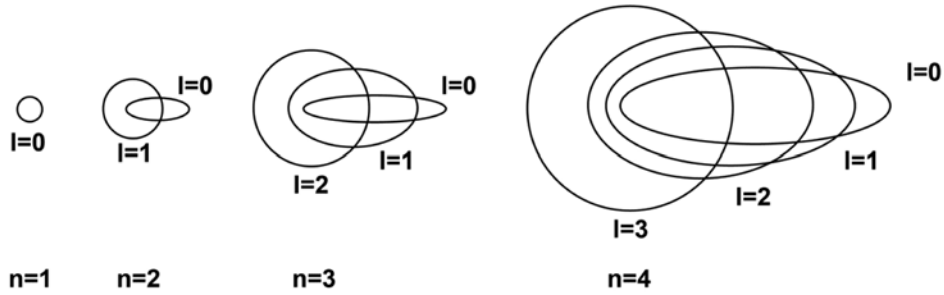
These satisfactory (S) presentations explicitly refer to how the Bohr-Sommerfeld model superseded Bohr's model, accompanied by diagrams of the elliptical orbits. Furthermore, it is important to note: a) Pauling's (1970) presentation refers to how the Bohr-Sommerfeld model in turn has been superseded by the wave mechanical; and b) Dickerson et al (1984) explicitly discuss how in the elliptical orbits an electron can penetrate the "screening shell' and thus achieve greater stability.

Following is an example of a textbook that was classified as mention (M):

> Bohr's hypothesis of circular orbits was modified in 1916 by Sommerfeld who postulated elliptical orbits. Even then, Bohr's scheme was condemned to failure as this problem could not be solved by classical mechanics (Whitten, Davis & Peck, 1998, p. 179).

This textbook did not present a diagram of the elliptical orbits and hence could not be classified as satisfactory (S).

It would be helpful for students and teachers if the textbooks present a graphical representation of the elliptical orbits in the Bohr-Sommerfeld model and following is a possible example:



It is plausible to suggest that presentations of Italian and U.S., general chemistry textbooks can easily be improved by incorporating some elements of the historical framework presented in this study and Niaz and Cardellini[5]. Textbooks that were classified as satisfactory (S) or mention (M) provided a much better picture of scientific progress as compared those that were classified as no-mention (N). For example, it would be helpful for students to understand that all atomic models (Thomson, Rutherford, Bohr) needed improvements. Bohr-Sommerfeld model was later subject to improvement (e.g., Pauli's exclusion principle) and finally replaced by the wave mechanical model of the atom.

4. Conclusion and Educational Implications

From a historical and pedagogical perspective presentations of textbooks in this study have various interesting features: a) For students it would be a surprise to know that despite its popularity and novelty, Bohr's model of the atom only explained the stability, ionization energy and the spectra of hydrogen-like ions, that is those possessing a single electron (H^+, Li^{2+}, Be^{3+}); b) Sommerfeld's innovation (auxiliary hypothesis) by introducing elliptical orbits, helped to restore the viability of Bohr's model to a certain degree; c) Bohr-Sommerfeld's model went no further than the alkali metals, which led scientists to look for other models; and d) This clearly shows that scientific models are tentative in nature. Despite the importance of including such aspects in order to facilitate students' understanding of nature of science only five Italian textbooks and three textbooks published in U.S.A., presented the Bohr-Sommerfeld model satisfactorily.

This leads to the question with which we started this study: Why has the Bohr-Sommerfeld model of the atom been ignored by general chemistry textbooks? In order to respond, let us consider the following: a) Most general chemistry textbooks refer to the atomic models of Thomson, Rutherford and Bohr in considerable detail; b) For anyone familiar with the literature this would represent the tentative nature of scientific theories; c) In contrast, general chemistry textbook authors simply ignore this aspect of the nature of science; d) Again, most general chemistry textbooks simply ignore the Bohr-Sommerfeld model of the atom, and even if they mention the model, very few consider it as a manifestation of the tentative nature of scientific theories. With this back ground, most readers would perhaps agree that textbook authors and chemistry teachers either do not understand or do not consider the tentative nature of scientific knowledge to be important. This justifies the inclusion of the Bohr-Sommerfeld model in textbooks (albeit briefly), especially if we want our students to understand how science progresses. Presentations of various textbooks (Lorenzelli, 1969; Dapporto and Spinicci, 1993; Dickerson et al. 1984; and Pauling, 1970) can provide guidelines for textbook authors in the future. At this stage it would be interesting to consider if the Bohr-Sommerfeld model of the atom (along with the models of Thomson, Rutherford & Bohr) is the right example for providing students with an illustration of the tentative nature of scientific theories. In our opinion, given the importance of atomic models in general chemistry textbooks[4], this example can indeed form an integral part of the text and a few additional lines can provide the context (an unfolding story) for understanding the tentative nature of scientific theories. This suggestion is based on the premise that various aspects of nature of science (e.g., tentative nature of scientific theories) need to be presented in the context of the different topics of the chemistry curriculum. Such presentations will help students to understand that nature of science is part of chemistry.

Finally, it is important to note that the need for incorporating history and philosophy in the science curriculum is essential if we want our students to understand how scientists do science, rather than just memorize algorithms.[14,15] In contrast, despite the reform efforts, textbooks continue to present science as a finished product ("final form") with no effort to scrutinize the historical record and the epistemological significance for students of the development of a model or theory.[16] Even when textbooks present historical details it invariably is in the form of names of famous scientists including their pictures, year and place of work and anecdotes, and all too often this becomes "fictionalized idealization".[17,18] Furthermore, in most parts of the world, textbooks constitute an important source for implementing the curriculum and determine to a great extent what is taught and learned about science.[19]

5. Acknowledgments

Authors would like to express their thanks to the four anonymous reviewers who provided constructive suggestions, which helped to improve the manuscript.

6. References

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18. M. Niaz, in: M. V. Thomase (Ed.), Science education in focus, Nova Science Publishers, New York, **2008**, pp. 15–65.
19. F. Abd-El-Khalick, M. Waters, A. Le, *J. Res. Sci. Teach.* **2008**, *45*, 835–855, p. 836.

Appendix 1

List of Italian General Chemistry Textbooks analyzed in this Study (n = 28).

A. Albertini, M. Avitabile, U. Benatti, V. Boido, F. Guerrieri, G. Liut, L. Masotti, A. Spini: Chimica generale, Monduzzi Editore, Bologna, **1993**.

R. Bertani, D. A. Clemente, G. Depaoli, P. Di Bernardo, M. Gleria, B. Longato, U. Mazzi, G. A. Rizzi, G. Sotgiu, M. Vidali: Chimica generale e inorganica, CEA, Milano, **2001**.

R. Bertani, D. A. Clemente, G. Depaoli, P. Di Bernardo, M. Gleria, B. Longato, U. Mazzi, G. A. Rizzi, G. Sotgiu, M. Vidali: Chimica generale e inorganica, 2nd Ed., CEA, Milano, **2006**.

I. Bertini, C. Luchinat, F. Mani: Chimica, CEA, Milano, **2004**.

P. Chiorboli: Fondamenti di chimica, UTET, Torino, **1980**.

P. Dapporto, R. Spinicci: Chimica, 2nd Ed., Edizioni CUSL, Firenze, **1993**.

G. Deganello, F. Maggio: Chimica generale, A. Delfino Editore, Roma, **1982**.

G. Fochi: Chimica da capire. Compendio di chimica generale con brevi cenni di chimica inorganica descrittiva, Edizioni ETS, Pisa, **2005**.

A. Immirzi: Chimica generale e inorganica, Liguori Editore, Napoli, **1992**.

V. Lorenzelli: Chimica. Per studenti di ingegneria, Edizioni Culturali Italiane, Genova, **1969**.

L. Malatesta: Chimica generale, Editrice Scientifica, Milano, **1970**.

L. Malatesta, S. Cenini: Principi di chimica generale con esercizi, 4th Ed., CEA, Milano, **1999**.

A. M. Manotti Lanfredi: Chimica, Pitagora Editrice, Bologna, **1996**.

A. M. Manotti Lanfredi: Applicazioni di fondamenti chimici, Pitagora Editrice, Bologna, **2004**.

A. M. Manotti Lanfredi, A. Tiripicchio: Fondamenti di chimica, CEA, Milano, **2001**.

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M. Nardelli, Introduzione alla chimica moderna, 2nd Ed., CEA, Milano, **1991**.

F. Nobile, P. Mastrorilli, La chimica di base con esercizi, 2nd Ed., CEA, Milano, **2006**.

F. Rodante, Lezioni di chimica per ingegneria, 2nd Ed., Edizioni Kappa, Roma, **1999**.

A. Sacco, Fondamenti di chimica, CEA, Milano, **1993**.

A. Sacco, M. Pasquali, F. Marchetti, Chimica generale e inorganica, CEA, Milano, **1998**.

M. Schiavello, L. Palmisano, Fondamenti di chimica, 2nd Ed., EdiSES, Napoli, **2006**.

P. Silvestroni, Fondamenti di chimica, Masson, Milano, **1997**.

A. Sirigu, A. De Renzi, A. Ripamonti, P. A. Temussi, N. Neto, C. Di Lauro, G. Paiaro, A. Paninzi, P. Ganis, G. Avitabile, G. Allegra, Chimica generale, 2nd Ed., Manfredi Editore,Milano, **1971**.

R. Spinicci, Elementi di chimica, Firenze University Press & Mc Graw-Hill, Firenze & Milano, **2004**.

P. Zanello, S. Mangani, G. Valensin, Le basi della chimica, CEA, Milano, **2001**.

Appendix 2

List of U.S.A. General Chemistry Textbooks Analyzed in this Study (n = 46).

P. Ander, A. J. Sonessa: Principles of Chemistry: An Introduction to Theoretical Concepts, Macmillan,New York, **1968**.

P. Atkins, J. Beran: General Chemistry, 2nd Ed., Scientific American Books, New York, **1992**.

P. Atkins, L. Jones: Chemical Principles: The Quest for insight, 2nd Ed., Freeman, New York, **2002**.

M. Bishop: An Introduction to Chemistry, Benjamin Cummings, San Francisco, **2002**.

G. M. Bodner, H. L. Pardue: Chemistry: An Experimental Science, Wiley, New York, **1989**.

J. E. Brady: General Chemistry. Principles and Structures, 2nd Ed., Spanish, Wiley, New York, **2000**.

J. E. Brady, J. R. Holum: Fundamentals of Chemistry, Wiley, New York, **1981**.

J. E. Brady, G. E. Humiston: General Chemistry: Principles and Structure, Spanish Ed., Wiley, New York, **1996**.

J. E. Brady, J. W. Russell, J. R. Holum: Chemistry: Matter and its Changes, Wiley, New York, **2000**.

T. L. Brown, H. E. LeMay, B. E. Bursten: Chemistry: The Central Science, 7th Ed., Prentice Hall, Englewood Cliffs, NJ, **1997**.

R. A. Burns: Fundamentals of Chemistry, 2nd Ed., Spanish, Prentice Hall, Englewood Cliffs, NJ, **1995**.

R. Chang: Chemistry, 6th Ed., Spanish, McGraw-Hill, New York, **1998**.

R. E. Dickerson, H. B. Gray, M. Y. Darensbourg, D. J. Darensbourg: Chemical Principles, 4th Ed., Benjamin/Cummings, Menlo Park, CA, **1984**.

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M. Hein: Foundations of college chemistry, Brooks/Cole, Pacific Grove, CA, **1990**.

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L. Jones, P. Atkins: Chemistry: Molecules, Matter, and Change, 4th Ed., Freeman, New York, **2000**.

J. C. Kotz, K. F. Purcell: Chemistry and Chemical Reactivity, 2nd Ed., Saunders, Philadelphia, **1991**.

W. T. Lippincott, A. B. Garrett, F. H. Verhoek: Chemistry: A Study of Matter, 3rd Ed., Wiley, New York, **1977**.

B. Mahan, R. J. Myers: University Chemistry, 4th Ed., Spanish, Benjamin/Cummings, Menlo Park, CA, **1990**.

L. J. Malone: Basic Concepts of Chemistry, 6th Ed., Wiley, New York, **2001**.

W. L. Masterton, C. N. Hurley: Chemistry. Principles and reactions, 2nd Ed., Saunders, Philadelphia, **1993**.

W. L. Masterton, E. J. Slowinski, C. L. Stanitski: Chemical Principles, 6th Ed., McGraw-Hill, New York, **1985**.

J. McMurry, R. C. Fay: Chemistry, 3rd Ed., NJ: Prentice-Hall, Upper Saddle River, **2001**.

J. W. Moore, C. L. Stanitski, P. C. Jurs: Chemistry: The Molecular science, Harcourt College, Orlando, FL, **2002**.

D. W. Oxtoby, N. H. Nachtrieb, W. A. Freeman: Chemistry: Science of Change, 2nd Ed., Saunders, Philadelphia, **1990**.

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Povzetek

V učbenikih splošne kemije je Bohrov model atoma obravnavan kot pomemben. Najpomembnejša pomanjkljivost tega modela je, da ne more pojasniti spektrov atomov, ki vsebujejo več kot en elektron. Da bi povečal razlagalno moč modela, je Sommerfeld predpostavil obstoj eliptičnih orbit. Pri tej študiji smo imeli naslednje cilje: 1) Na osnovi zgodovine in filozofije znanosti določiti kriterije; in 2) Na osnovi določenih kriterijev ovrednotiti univerzitetne učbenike splošne kemije, izdane v Italiji in ZDA. Predstavitev v učbeniku je bila ocenjena kot »primerna«, če je vključevala opis Bohr-Sommerfeldovega modela atoma skupaj z diagrami eliptičnih orbit. Od 28 učbenikov, izdanih v Italiji, je bilo pet učbenikov ocenjenih kot »primernih«, od 46 učbenikov izdanih v ZDA pa le trije. Ta študija je za izobraževanje pomembna iz več razlogov: a) Pokaže, da je Sommerfeldova dopolnitev z vpeljavo eliptičnih orbit pomagala ohraniti uporabnost Bohrovega modela atoma; b) Ker je Bohr-Sommerfeldov model uspešno pomagal samo pri razlagi atomskih spektrov alkalijskih elementov, je to vodilo znanstvenike k iskanju novih modelov; c) To očitno dokazuje, da se znanstveni modeli razvijajo; d) Avtorji učbenikov in učitelji kemije menijo, da razumevanje take narave naravoslovnega znanja ni pomembno; e) Vključitev Bohr-Sommerfeldovega atoma v univerzitetne učbenike bi pomagala študentom razumeti razvoj znanosti.