THE INTERNATIONAL YEAR OF THE PERIODIC TABLE: AN OVERVIEW OF EVENTS BEFORE AND AFTER THE CREATION OF THE PERIODIC TABLE

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Abstract

It has been 150 years since D.I. Mendeleev formulated the Periodic law and expressed it visually in the form of a table of elements in 1869. As is clearly well known today, Mendeleev's ideas, confirmed by the discovery of the elements he predicted, turned out to be very promising indeed. However, Mendeleev was not the first, nor the only scientist to have investigated the periodic arrangement of the elements. With this in mind, the present paper seeks to highlight some of the other efforts made in the field during Mendeleev's lifetime.
Keywords: *D. Mendeleev, periodic table, table options, history of science*.

Introduction

If we examine the decade preceding the creation of Mendeleev's periodic table, we will find that several attempts had already been made with a view to classifying elements according to their atomic mass.

Among such endeavors it is possible to note the tables offered by William Odling (England, 1857-1864), the spiral offered by Alexandre-Émile Béguyer de Chancourtois (France, 1862), the octaves offered by John Alexander Reina Newlands (England, 1864) and the tables offered by Julius Lothar von Meyer (Germany, 1864, 1870). These were all proceeded, however, by the very first effort made in this direction, namely were the triads proposed by Johann Wolfgang Döbereiner (Germany, 1817-1829). These aforementioned attempts have already been examined and studied in detail by earlier scholars which are cited in the full version of the present article and which are also presented in a visual form.

Unfortunately, it should be recognized that all these scientists had also failed in either finding the key thread in their assumptions (which were later shown to be correct), or in correctly interpreting the patterns in their theoretical framework. In this respect, it should be noted that even D. Mendeleev himself and his colleagues even were forced to defend the priority of their discovery (Mendeleev, 1871a; Chugayev, XVI).

Moreover, it is especially important to note that none of the attempts that preceded Mendeleev's 1869 publication made it possible to fully establish a general pattern applicable to all the elements that were known at the time of publication of his periodic

table. In addition, none of them even provided for the possibility of correcting atomic masses, let alone for the possibility of predicting (!) undiscovered elements. Indeed, and almost forty years later, D. Mendeleev himself wrote in his diary: "Apparently, the future law does not threaten periodic law with destruction, but only superstructures and development promises" (Dobrotin). These words turned out to be prophetic. 63 elements were known in 1869, while 118 elements are known as of 2019, and yet all can be placed uniquely in Mendeleev's table.

At least 700 different versions of Mendeleev's table have been offered thus far. Some of these are based on the search for a mathematical justification for periodic dependence, while others are an attempt at a graphical representation of the laws of nature.

With this in mind, the present study seeks to consider and study several types or versions of periodic tables proposed by their authors during Mendeleev's lifetime.

Types of Periodic Tables

As proposed in the initial model, and as a general rule, 19th century scientists only considered a short, 8-column, form of the periodic table of elements, which is why we only considered these versions of the tables included in the present study. Furthermore, the scientists, who offered suggestions pertaining to the placement of elements in a graphic form, included Danes, Germans, and Britons, as well as Russians. This, in turn, serves to underline the argument suggesting that science has no boundaries and that true discoveries always become the property of and belong to the humanity at large rather than to a particular nation.

As we noted above, the chemical community was well aware of the fact that several dozens of attempts to classify elements had been made before our great compatriot, D.I. Mendeleev, plunged into this question. The methodological needs associated with the preparation of a student textbook, based on a single logical system, was what - in large part - led Mendeleev to the formulation of a law, that objectively existed in nature, but was unknown to any scientist at that point in time. The textbook in question was Basics of Chemistry (Mendeleev, 1868), which contained Mendeleev's own formulation of the law, as follows: "the physical and chemical properties of elements, manifested in the properties of the simple and complex bodies they form, are periodically dependent (form a periodic function, as they say in mathematics) on their atomic weight" /attributed to D.I. Mendeleev - S.T., E.T./ (Mendeleev, 1871b, p. 941).

Since we work at school, we have the opportunity to acquaint ourselves and our students with the chemical-historical events of the 19th century. In this respect, we will focus on the rather rare versions of the table of elements stored in our school's small collection. Moreover, we also wish to posit that the tables considered below are of historical and chemical, as well as chemical and mathematical, interest. With this in mind, we shall begin our journey with the periodic table proposed in Kazan by F. Flavitsky (Figure 1) in 1887 (Flavitsky).

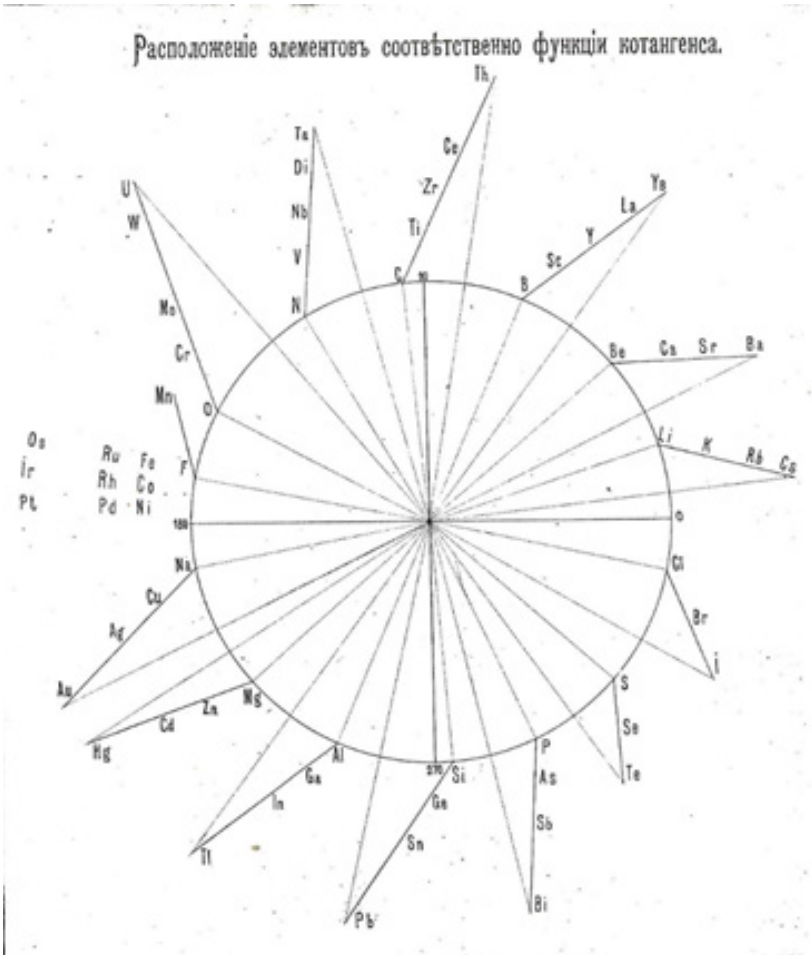

Figure 1. The location of the elements, with respect to the cotangent function by F.M. Flavitsky.

The next stop in our journey is the table proposed by Lothar Meyer in 1894, which is interesting because it is presented on a cylinder (Meyer). We will then proceed to the table offered by J. Thomsen from Denmark, in 1895 (Thomsen, 1895a, 1895b); the spiral triangle offered by N. Delone of St. Petersburg, in 1898 (Delone) and the spiral eight (the first spatial table) offered by W. Crookes of London, in 1898 (Crookes).

With this in mind, it is worth noting that Mendeleev himself opined that "…the spiral arrangement of the elements ... I consider it marginally applicable and largely artificial…" (Mendeleeff, 1871a, p. 352). While this is probably true from a scientific perspective, visuals are also important when teaching students and it is in this respect that spiral versions of the table offer a clear advantage.

Our journey ends with a study of the periodic table proposed by the artillery colonel Nikolai Nechaev in 1893 (Figure 2) (Nechaev). Nechaev's approach to the table is original in two respects: Firstly, it is a special, rather than a planar, representation of

periodic dependence. Secondly, Nechaev presented his table in the form of a projection of rotational bodies onto a plane represented as truncated cones installed alternately in the form of a tower, of which there are no surviving copies.

That said, we would also like to mention one more version of the periodic table, namely the one offered by V. Ipatiev. Ipatiev's version was one of the first to have been applied in a school textbook, and is also concise and accompanied by a detailed methodological commentary. More specifically, Ipatiev is important in directing our attention to the fact that an essential feature common to all elements should be chosen if the elements are to be systematized. Furthermore, Ipatiev also offered another crucial insight in arguing that this selected feature must satisfy certain conditions, namely: 1) it must be measurable, 2) it must be common to all elements and 3) it must be paramount, i.e. that all the remaining properties of the elements must depend on it [Ipatiev].

Figure 2. Scanning of the projection of rotational bodies in the form of truncated cones as used in Nechaev's spatial construction of the periodic system, 1893.

In this respect, we would like to first and foremost direct the reader's attention to the fact that only Crookes' 1898 table (Crookes) contains the inert elements.

It is important to note that many variants of the periodic table of the elements are accessible to those who wish to study them. Particularly instructive in this respect is the collection assembled by the famous chemist and science communicator, as well as a participant of the XXIst Mendeleev Congress scheduled for September, and the Vice President of the London Royal Society, Nottingham University Professor Sir Martyn Poliakoff. Professor Poliakoff also kindly presented part of his collection at the second chemistry teaching conference in Moscow in February 2019. A similar collection is also available for public viewing at the Riga Polytechnic University. This second collection was gathered and donated to the university by Mikhail Gorskis (Iecava, Latvia).

Finally, we wish to stress that the table versions presented by us above are rare and are not necessarily part of either the Poliakoff or Gorskis collections.

Conclusions

D.I. Mendeleev conceived and formulated a system of elements, about which he quite deservedly argued that: "it would be more correct to call my system periodic because it follows from the periodic law" (Mendeleev, 1871b). The publication of his table also represented the breaking of a metaphorical intellectual dam in the sense that sources suggest that between 500 and 700 versions of the table have been published or discovered thus far! Note, however, that these are all versions of *Mendeleev's* original periodic table of elements!

We would also like to note that the original version of the table prepared by Mendeleev himself and sent to colleagues in February 1869 entitled "The experience of a system of elements based on their atomic weight and chemical similarity" [Journal]. In light of this, it is possible that subsequent translations sounded like "periodic table" and were offered without the name of the author. It is also quite possible that Mendeleev's name itself will be included in the title of the table of elements in he created as we celebrate the 150th anniversary of its creation.

In closing, we hope that this study, which has plunged you into chemical antiquity, will also allow you to better understand how you can reach the highest peaks in science by joining forces with the global scientific community!

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References

Chugaev, L. A. (1913). *Periodicheskaja sistema himicheskih jelementov* [Periodic system of chemical elements]. Sankt-Peterburg: izd-vo "Obrazovanie".

Crookes, W. (1898). On the position of helium, argon and krypton in the scheme of elements. *Proceedings of the Royal Society, 53*, 408-411.

Delone N. (1898). *Graficheskoe izobrazhenie periodicheskoj zakonnosti himicheskih jelementov* [Graphic depiction of periodic legitimacy of chemical elements]. Sankt-Peterburg.

Dobrotin, R., Karpilo, N., Kerova, L., & Trifonov, D. (1984). *Letopis' zhizni i dejatel'nosti D.I. Mendeleeva* [Chronicle of the life and work of D.I. Mendeleev]. Leningrad: Nauka. Zapis' ot 10 ijulja 1905 g.

Ipat'ev, V., & Sapozhnikov, A. (1904). *Kratkij kurs himii po programme voennyh uchilishh* [A concise course in chemistry for military academies]. Sankt-Peterburg: tip. V. Demakova.

Flavickij, F. M. (1887). *O forme, otvechajushhej periodichnosti svojstv jelementov* [On the function corresponding to the periodicity of the properties of the chemical elements]. Kazan': tipografija Imperatorskogo Universiteta.

Zhurnal Russkogo Himicheskogo Obshhestva [Journal of the Russian Chemical Society] (1869). T. 1, vyp. 2 i 3, s. 35].

Mejer L. (1894). *Osnovanija teoreticheskoj himii* [The foundations of theoretical chemistry]. Sankt-Peterburg: K.L. Rikkert.

Mendeleev D. (1868). *Osnovy himii* [Basics of chemistry]. Sankt-Peterburg: izdatel'stvo Tovarishhestva „Obshhestvennaja pol'za".

Mendeleeff (1871a). *Zur Frage* über *das System der Elements* [To the question about the system of the Elements]. *Berichte der Deutschen Chemischen Gesell schaft zu Berlin, IV,* s. 348-352.

Mendeleev D. (1871b). *Osnovy himii* [Basics of chemistry]. Sankt-Peterburg: izdatel'stvo Tovarishhestva "Obshhestvennaja pol'za".

Nechaev N. P. (1893). *Graficheskoe postroenie periodicheskoj sistemy jelementov Mendeleeva. Sposob Nechaeva* [Graphic construction of Mendeleev's periodic system of elements. Nechaev's way]. Moskva: tip. Je. Lissnera i Ju. Romana.

Thomsen J. (1895a). *Systematische Gruppierung der chemischen Elemente* [Systematic grouping of chemical elements]. *Zeitschrift für Anorganische Chemie, 9*, 190-193.

Thomsen J. (1895b). *Uber die mutmassliche Gruppe inaktiver Elemente* [About the alleged group of inactive elements]. *Zeitschrift für Anorganische Chemie, 9*, 283-288.