2019 – THE INTERNATIONAL YEAR OF THE PERIODIC TABLE OF CHEMICAL ELEMENTS

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Abstract. The 150th anniversary of the discovery of Periodic Table of chemical elements by Dmitri Mendeleev in 1869 will be celebrated in 2019 year. The key role of Mendeleev's work on elements systematization is presented in brief together with the indispensable efforts of many other chemists too. Different types of Periodic tables and the development of ideas concerning the structure of a table or other graphical representations of the existing state-of-art over years are shown in a more historical point of view.

Keywords: 150th anniversary; periodic table; history of discovery; Dmitri Mendeleev

Connotation of periodic table and the hint chemical nuances

"Along as chemistry is studied there will be a periodic table. And even if someday we communicate with another part of the universe, we can be sure that one thing that both cultures will have in common is an ordered system of elements that will be instantly recognizable by both intelligent life forms" – J. Emsley. Undeniably, it has been estimated within 150 years (celebrated in 2019) since the introduction of the famous Mendelev's table as one of the most fruitful and unifying ideas in the whole modern science that remains at

the heart of chemistry. The development of the Periodic Table of the Elements is one of the most significant achievements in science and a consolidating scientific concept, with broad implications in Astronomy, Chemistry, Physics, Biology and other natural sciences. It is a unique tool enabling scientists to predict the appearance and properties of matter on Earth and in the Universe. Undisputed champion above all others, Mendelev's *modus operandi* regarding the placement of elements and the foreseen *ad hoc* arguments make it happen on February 17, 1869, when the first Periodic Table elaboration appeared in the Russian literature, the first volume of the journal of the newly established Russian Chemical Society. Thus, the date March 1 (new style calendar) could be assumed to be the exact official birthday of the distinguished table. Today trends can be observed among the all 118 elements going across and down the table and each could be identified through its unique "fingerprint". From the discovery of the first metals gold and copper until the end of the 17th century, some 7700 years, only 12 metals were known by mankind. Nevertheless, gradually with increasing complexity of human life, the people's need of new materials naturally augment to the currently known 86 metals (80 % inside Periodic Table). In proclaiming an International Year focusing on the Periodic Table of Chemical Elements and its applications, the United Nations (General Assembly 72nd Session held on 21 December 2017, during its 74th Plenary Meeting proclaimed 2019 as the International Year of the Periodic Table of Chemical Elements (IYPT2019)) has recognized the importance of raising global awareness of how chemistry promotes sustainable development and provides solutions to global challenges in energy, education, agriculture and health. Indeed, the resolution was adopted as part of a more general Agenda item on Science and technology for future developments and innovations in industrial endeavors.

The reinforcement and the idea of the chemical elements' order and the laws to which they obeys are exceptionally long historical process, Fig. 1. Over time the sense of Laws of chemical elements has been developing and every next theory has surpassed or improved the previous one already suggested by some great chemists. The knowledge about the nature of compounds and elements is at the heart of matter philosophy in ancient Greek times recognizing only earth, water, air and fire. The four element hypothesis and the four essential qualities i.e. hot or cold, and wet and dry in the form of one additional square remained in favor through the Middles Ages and *de facto* stimulated the pursuit of alchemy for more than a millennium in Greece, Egypt, Arabia, China and the Occident. It is somehow not so surprising that the particular attempt of alchemists was to change some base metals at ancient time into one noble metal, gold, one of the most treasured substance in vogue, since the dawn of civilization, Fig. 2.

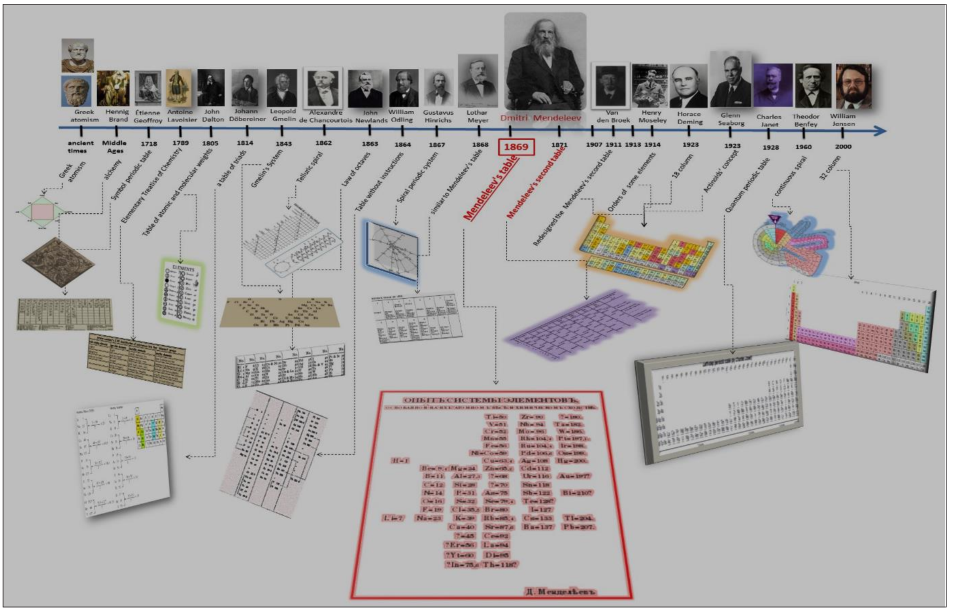

Figure 1. Reinforcement of the Periodic Table of chemical elements in the course of history

Figure 2. The Panagyrishte Treasure is a Thracian 24-karat gold masterpiece of nine vessels (a phiale, an amphora, three oinochoai and four rhytons) created 400 BC – 300 BC. National Museum of History, Sofia

Chronically, we have to mention imperatively the first published list consisting of approximately 33 elements and substances (gases, metals, nonmetals and earths) in 1789 by the famous French chemist Antoine Lavoisier. Besides, his predecessor, the French physician and chemist Étienne Geoffroy who was constructed the first affinity table in 1718 entitled "Table of affinities between different substances" containing 24 species that could react one another. Subsequently 1829, the appearance of the Döberainer's triads including groups of three elements *a propos* their physical properties (Li, Na, K; Ca, Sr, Ba; S, Se, Te and Cl, Br, I). Hence "triads" were converted to tetrads by Jean-Baptiste Dumas after affixing of F, O or Mg in the late 1854. Thereafter, in 1862 someone else, monsieur Chancourtois has arranger the chemical elements following the helix (a spiral graph) with a step of 16 (the approximate atomic weight of oxygen) between each other in consequence of the corresponding atomic weights. Consecutively, John Newlands (1864) has disposed the 62 known elements into eight groups i.e. "law of octaves" in order to find musical harmony (in which tones display a repetition comprises an interval of eight notes), howbeit again settled on their physical properties. Lothar Meyer was one of the pioneers elaborating a periodic table of chemical elements too working at the same time as prof. Mendeleev and independently has published a very similar table version. But this is another story. The Paramount law in the Chemistry and Natural sciences is of course the Mendeleev's law – Periodic law – the order of chemical elements as a results from the innate dialectically outcome from the science boost. In literature it's called *the Divine law* as well, because it creates and formulates the basic principles in Chemistry and the world scientific community respects and acknowledges it till nowadays.

The four most recent elements added into the Periodic Table, with the approval of their names and symbols, on 28 November 2016 by IUPAC are: nihonium (Nh), moscovium (Mc), tennessine (Ts), oganesson (Og), respectively for elements 113, 115, 117, and 118. The ending of the names reflects and maintains historical and chemical consistency: "-ium" for elements 113 and 115 and as for all new elements of groups 1 to 16, "-ine" for element 117 that belongs to group 17 and "-on" for element 118 element incorporated into group 18 (Fig. 3). Certainly, the discovery of a new chemical elements correlates strongly with the historical events that happens in the countries and depends on the financial circumstances also. Element with Z=113 is the first that has been discovered in Asian country. Nihon is one of the two ways to say "Japan" in Japanese and literally mean "the land of rising sun". Despite the fact that Japanese researchers have some background *vis-à-vis* discovery of elements 43 and 75 and the trailblazing work done by Masataka Oganawa. Moreover, the team at RIKEN also has hopes that prides and faith in science will displace the lost trust of those who suffered from the 2011 Fukushima nuclear disaster.

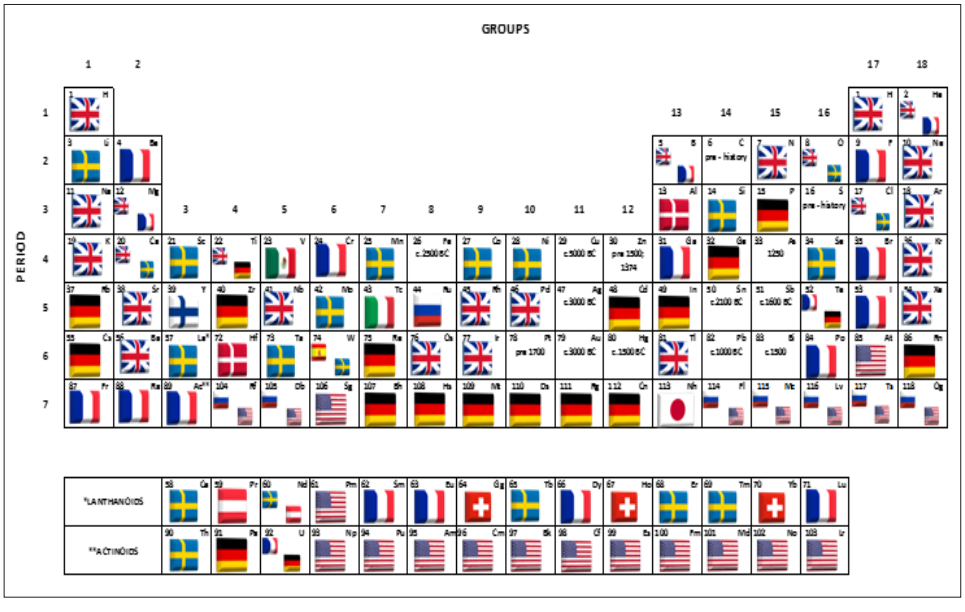

Figure 3. Periodic table with nationality of the countries where the chemical elements were discovered

Afterward, element 119 should be the first to begin building of 8 period of the Periodic Table, which should contain 50 elements, as besides the 8s, 8p, 7d, 6f-sublayers also includes a 5g-sublayer containing 18 elements. Calculations based on the Dirac-Fock method have shown that for elements 119 – 172 the filling of the electron sublayer should be in the following approximate order: 8s <5g <$8p_{1/2}$ <6f <7d <9s <$9p_{1/2}$ <$8p_{3/2}$. However, it is extremely difficult to assume that elements with very large atomic numbers will be synthesized and so far no answer can be given on where borderline, the upper limit of the Periodic Table really is.

The role of Mendeleev' adroitness

Under the above mentioned circumstances it is not true to conclude that the Periodic Table was discovered only by the Russian chemist or even together with Lotar Meyer autonomously. Why in this story we are singling out only Mendeleev's name then? He has a genius idea to make 200 printed copies of his table with a title "*An experiment on a system of elements based on their atomic weights and chemical similarities*" and sent them to various chemists not only in Russia but in the rest of Europe as well. In view of original and logic way D. I. Mendeleev postulated that the chemical elements exist in a periodical order regulated by their atomic weights. As a result of the discovery of the Periodic Law is a natural creation of the Periodic

Table. Mendeleev's merits are indisputable, but the one most useful, as a result of his cogitation was that he successfully predicted the existence of several elements which were not known at that time. One can see no more than four "?" in the first version (1869), left by Mendeleev vacant spaces "gaps" for future newcomers in the table, while nearly eleven "–" appeared in the second proposition from 1871. Indisputable, fact that clearly shows the depth of Mendeleev's chemical know-how specifically the foreseen chemical elements existence. As a whole, these predictions were accepted by many chemists as an unheard audacity. His servitude looks even more amazing when the newly discovered chemical elements is putted in the correct place in Periodic Table and the concept of periodicity was validated in next years. The most famous predictions to be underlined herein are for Sc, Ge and Ga. In 1875, the French chemist Emile Lecoq de Boisbaudran has succeed to isolate the new element gallium *id est* Mendeleev's eka-aluminium (*eka-* from the Sanskrit a digit 1). It is interesting to note that the inaugural density established by monsieur Boisboudran was no so correct (4.7 g/cm^3), but after Mendeleev's persistence, who noticed that it must be *ca.* 5.9 – 6.0 g/cm^3, the omitted error by the French chemist was corrected to 5.904 g/cm^3. The other predicted elements eka-silicium and eka-boron are named also to European countries, Ge by Winkler in 1886 and Sc by Nilson in 1879. Over and above C. Winkler has asked Mendeleev, if it is possible to name the discovered element in the mineral argyrodite Ag_8GeS_6, germanium: a manifestation of great respect. Clearly, Dmitri Mendeleev predictions were spectacularly fruitful and many of the foreseen chemical and physical characteristics and properties described by him become true so many years later. Thus, because of the discovery of these three elements the Russian chemist has received adequate attention and recognition worldwide among chemists.

The Periodic law has been discovered in 1869 as a result of Mendeleev's hard work and the future advancement concerning the structure of atom is obvious even through around 40 years later. The elements if arranged according to their atomic weights, exhibit an evident periodicity of properties. This law is still useful today despite the correction from 1913 initiated by Henry Mosely thanks a X-ray spectroscopy, which postulates that the elements are not ordered by their mass weight but by the number of the protons in their nucleus, ergo their atomic number (Z) indeed. *Fortes fortuna juiat.*

Honorarium, legacy and…. a bitter pill to swallow

Unfortunately, prof. Mendeleev has not be awarded with a Nobel Prize for chemistry admitting the two unsuccessful nomination in 1905 and 1906 and after that in 1907 year when the nomination was rejected also. Maybe it is worthy to remember first of all, that sir William Ramsey has received this prestigious medal in 1904 in recognition of his service in the discovery of the inert gaseous elements in air, and his determination of their place in the periodic table *videlicet* all these

newcomers have without any great difficulty be fitted into the Mendeleev's table as a group zero, after personal agreement with Mendeleev. As a matter of fact, in 1906 D. Mendeleev was selected by the prize committee to win the honor, but the Royal Swedish Academy of Sciences stepped in and overturned the decision. Political reason or personal motives are behind this adjustment: a gross injustice according someone or many. Thus, the name of the Swedish chemist Svante Arrhenius, appeared in this place somehow spontaneously, who himself had won the prize in 1903 (first Swede with a Nobel Prize) for his theory of electrolytic dissociation. It is a well-known fact that Mendeleev had been an outspoken critic of the proposed theory, and consequently Arrhenius seized the opportunity as the perfect chance to a degree to squeeze a few sour grapes. Arrhenius was involved in setting up the Nobel Institutes and the Nobel Prizes as well as he was a member of the Nobel Committee on Chemistry. In the public eye Arrhenius is someone that take advantage of his positions to arrange prizes for some of his friends (for example Jacobus van't Hoff, Wilhelm Ostwald, Theodore Richards) or to attempt to deny them to his enemies (case history: Paul Ehrlich, Walther Nernst, Dmitri Mendeleev). *Nil novi sub sole*. The Nobel Prize in Chemistry for 1906 was awarded to the French chemist Henri Moissan "in recognition of the great services rendered by him *a propos* isolation of the element fluorine, and for the adoption in the service of science of the electric furnace", five votes to four i.e. a margin of one vote solely. All attempts to nominate Mendeleev in 1907 were again frustrated by the absolute opposition of Arrhenius. *De facto* Henri Moissan was actually a great chemist working in the field of inorganic chemistry with too many authorized achievements. Moissan died suddenly in Paris in February 1907 by cause of an acute case of appendicitis (aged 54), while Mendeleev died one month earlier on January the same year in Saint Petersburg from influenza at the age of 72.

Prof. Mendeleev has occupied a cell in his own table between the names of other genius as a recognition for his devotedness and persistence to chemistry. The scientific team working at the University of California, Berkeley, including G. Seaborg, G. Choppin, A. Ghiorso, B. Harvey and S. Thompson has achieved to obtain a new element with a periodic number 101 in 1955 year. This new element is somehow rather unusual with a half-life of 77 minutes only, produced by another isotope named after atypical genius ^{253}Es like a target. Actually ^{256}Md turns to be the first isotope of any element to be synthesized ever with only one atom at a time. In total, seventeen mendelevium atoms were produced till now. The research team has decided to name the element after the Russian chemist, Father of the Periodic Table, in that event they have received a carte blanche from the responsible institutions in USA, in fact not to forget that the discovery came during the Cold War. Veritably, a scientific gest widely recognized not only in ex-communist Block. The official name "mendelevium" was approved by the IUPAC at the end of the same year

(1955) nevertheless with symbol Mv, which was changed to Md in the next IUPAC General Assembly hold in Paris during 1957 year.

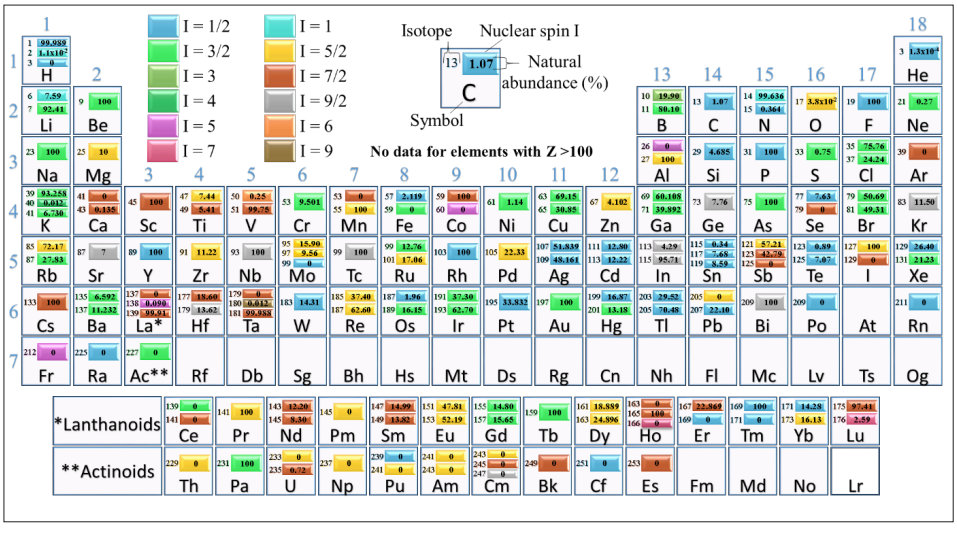

Figure 4. NMR Periodic table of chemical elements

Nowadays different types of Periodic Table are developed and put into service in almost all branches of science and scientific daily life. An example of modern version of periodic table, containing non-standard information is the proposed NMR Periodic Table, Fig. 4. This elaborated table includes particular data about natural abundance and nuclear spin of familiar chemical isotopes without exception having non-zero spin, in-depth practical use for NMR analysis.

Conclusion

Chemical Elements have always played a vital role in the daily lives of the *Homo sapiens* and are so crucial for humankind and our planet as well as for all branch of industry. The International Year of the Periodic Table of Chemical Elements will give an opportunity for the chemistry community to show how they are essential to linking cultural, economic and political aspects of the global, modern society through a common language, the language of chemistry, whilst also celebrating the genesis and evolution of the periodic table over the last 150 years.

Mendeleev's work establishes *logos, cosmos* into chemical knowledge and natural laws through creation of Periodic Table and the endorsement of Periodic Law. 2019 is the year to remember and commemorate the brilliant work and activities of Dmitri Ivanovich Mendeleev, who thief the *"fire"* in the development of chemistry

like a science. Today, 150 years later, we can say without hesitation or any doubts that the Mendeleev's Law is a Constitution of the Chemistry and the Periodic Table is the *Magna Charter*. The scientific contribution and influence of Mendeleev's activity are still immense among contemporary chemists. Finally, his Renaissance personality and work being an expression of a true academic tradition and spirit that we should appreciate, preserve and impart for future generations, no ifs ands or buts about it. This is the growth path of Mendeleev's life and work which we are all bound to continue with dignity and thought to eternity.

As a final word to the wise, Mendeleev's words written in the preface of his book entitled "Fundamentals of Chemistry": "By presenting my book to the scientific community, I know there are flaws and shortcomings in it, but I hope that people will be recalled to know that science is immense and that the human mind is limited."

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