A DREADED ENEMY OR AN INSPIRING HELPER?

PETR DISTLER

Department of Nuclear Chemistry, Czech Technical University in Prague, Břehová 7, 115 19 Praha 1; Gymnázium ALTIS, Dopplerova 351, 109 00 Praha 10
petr.distler@fjfi.cvut.cz

Kew words: periodic system of elements, D. I. Mendeleev, teaching chemistry, relations between school subjects

Celebrating its 150th birthday in 2019, it continues to grow and is most often encountered in chemistry classes. Any idea what it is? Yes, it's the periodic table of the elements. Some elements have been with us for hundreds or thousands of years and influence our daily lives. Isn't it a pity, therefore, that this magic table and the information it contains is mostly used only in chemistry, without crossing over into other subjects? And isn't it also a pity that primary and secondary school pupils see it as a dreaded enemy rather than a useful tool? Let us look together at the prospects of using the periodic table of elements across different educational areas.

The United Nations (UN) has declared 2019 the International Year of the Periodic system of elements to highlight the important role of science (in view of the fact that you are reading *Chemické listy* (*Chemistry Letters)*, with an emphasis on chemistry, of course) in everyday life. At the same time, this year is seen as an opportunity to showcase recent scientific discoveries and current challenges. For chemistry, these are mainly related to the environment, energy, industry, agriculture, health and education. The UN and its international expert agencies (e.g. UNESCO) organize various events for the public and schools to get as many people as possible thinking about this topic[1].

150 years ago, Dmitri Ivanovich Mendeleev had to think too, when he arranged the 63 known elements into the periodic table as we know it today. What's more, he predicted very accurately the properties of three yet undiscovered elements. An example of the proposed table can be seen in Fig. 1. He divided the elements into 8 groups and 5 periods, and each period consisted of two rows[2]. He received many awards and memberships in prestigious scientific societies for his discovery, but he did not win the most famous scientific award, the Nobel Prize. The element mendelevium, with the proton number 101, is named in his honour.

Let us now return to the classroom and to history lessons. Let's start with prehistory, which is usually given a large amount of time. In prehistoric times, mankind knew 11elements, which are shown in Fig. 2 together with those discovered in the Middle Ages. Why were known just these elements? What properties did they have that led humans to discover and use them? And what was the main benefit of bronze above the properties of copper or tin alone? The fact that the chemical elements played an important role is shown, among other things, by the fact that the Stone Age was followed by the Bronze Age and the Iron Age. The use of copper-tin alloys and then iron changed the way of society functioning. In particular, the use of bronze was accompanied by social differentiation – society became more structured and a larger part of the population moved from agriculture to crafts. This was also

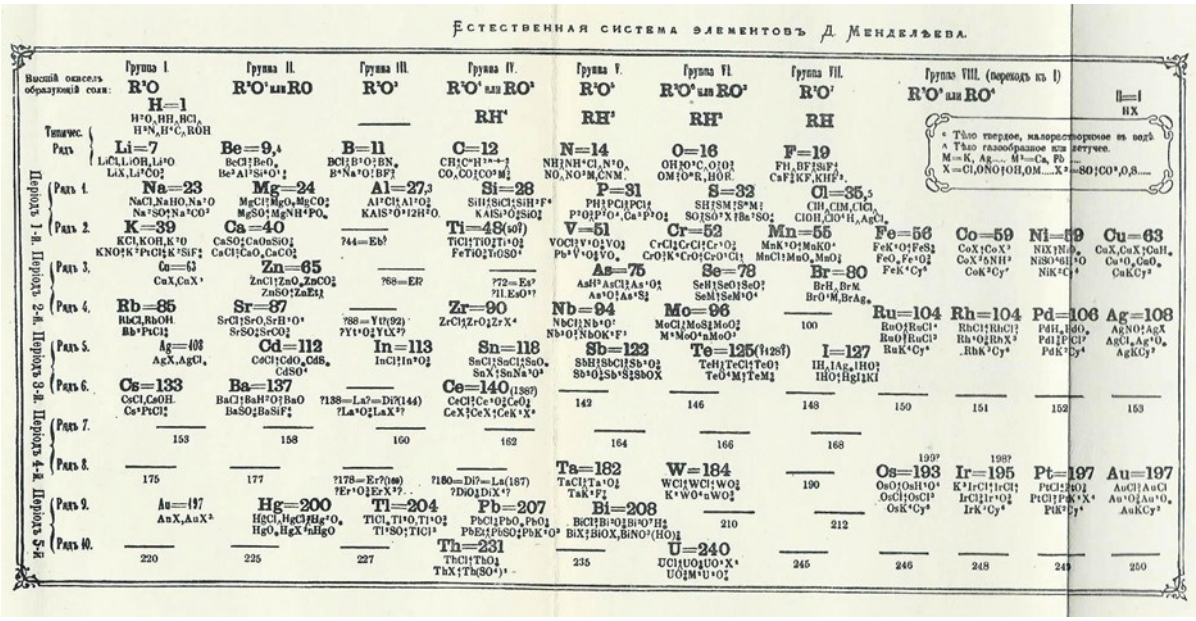

Fig. 1. **The D. I. Mendeleev's periodic system of elements from 1869** (ref.[2])

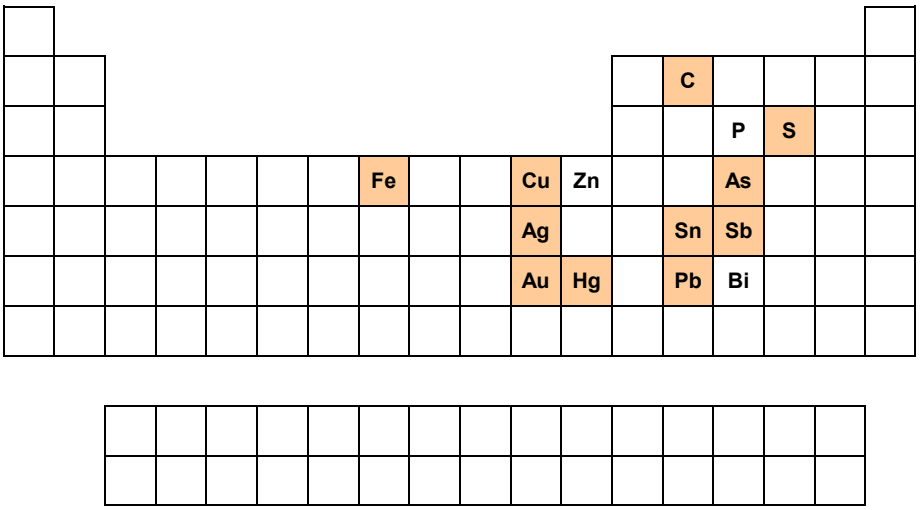

Fig. 2. **Elements known in prehistory** (brown-tinged) **and in the Middle Ages** (on white background)

linked to access to raw materials, techniques for their processing and subsequent use, whether for their own benefit or for barter. The Iron Age then allowed further development of weapons and tools, resulting in major changes in e.g. agriculture[3].

The 63 elements according to D. I. Mendeleev's 1869 data are highlighted in Fig. 3. As we know, the elements are arranged on the basis of their properties, which are a periodic function of their atomic weights. D. I. Mendeleev predicted the properties of the new elements scandium, gallium, and germanium precisely on the basis of the version of the periodic law he formulated[2]. Based on his knowledge of the properties of the elements in the group, he predicted the properties of the new elements and thus "filled in" the missing boxes of the 4th period. The predicted properties were then confirmed by the discovery of the three elements mentioned within 1875 and 1886.

An activity similar to D. I. Mendeleev's scientific procedures was introduced by Olga Mokrejšová in her book Modern Chemistry Teaching. In the first stage, pupils are given a table, which is shown in Fig. 4. Pupils are told what each piece of information means (state, density, hardness, electrical conductivity, etc.). The pupils' task is to compare the properties of the elements in each column and try to formulate their change of properties in a group. For example, that the density of the gas in the third column increases as the proton number increases. In the second part, they are given 8 cards representing 'unknown'

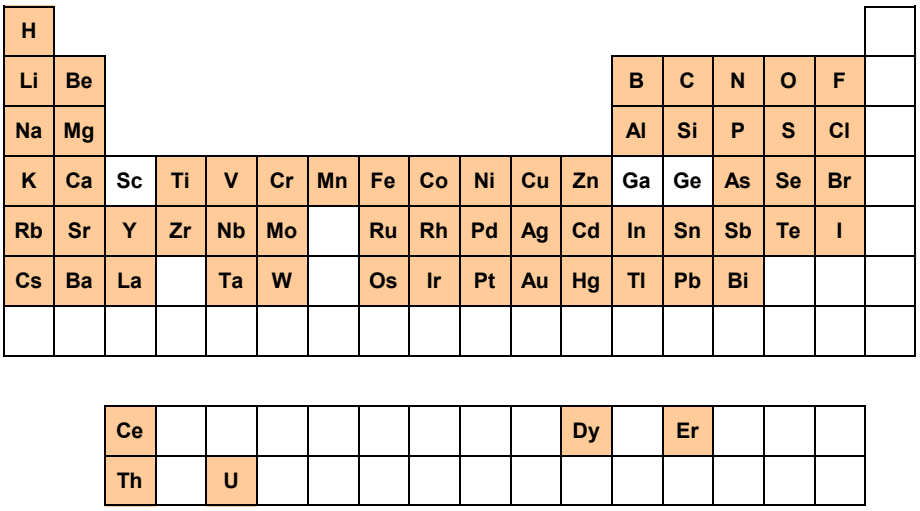

Fig. 3: **Elements known in 1869** (brown-tinged) **and three elements predicted by D. I. Mendeleev** (white background)

		0.000 18 very bad –269 °C insoluble
solid 0.534 soft good 180 °C reacts		gas 0.000 90 very bad –248 °C insoluble
0.971 soft good 98 °C reacts rapidly	gas 0.003 21 very bad –101 °C small reactivity	gas 0.00178 very bad –189 °C insoluble
0.86 soft good 64 °C reacts explo-sively	3.12 very bad –7.2 °C very little soluble	
	4.94 soft very bad 114 °C very little soluble	gas 0.00585 very bad –112 °C insoluble

Fig. 4. **The example from the book Modern Chemistry Teaching** (adapted from ref.[4])

elements and they try to match these to the blanks in the table based on the properties given. In the third part, they will learn what groups of elements they are, complete the labels of each element, and compare their properties with those given in the periodic table or in the textbook. As the author states, "*this exercise facilitates pupils' understanding of the periodic law, the properties of the elements of each group, and also develops pupils' reasoning skills*"[4].

The elements known in prehistoric and medieval times are followed by the graph in Fig. 5, which shows how many new elements were discovered in a given decade. Let us look together at the three local maxima in the early and late 19th century and in the 1940s[5]. What is behind them? In general, the Industrial Revolution encouraged this trend. Behind the first maximum was the discovery of electrolysis, which made it possible to prepare new metallic elements. The second peak could be called the *rare earth peak* because it was due to the wide discovery of rare earth elements and noble gases. And the third peak is related to the discovery of transuranic elements as a result of the construction of the nuclear bomb and other related technologies. From the third maximum, we move smoothly from history into physics – namely, the discovery and use of nuclear fission, and the discovery of transuranic elements. Physics subsequently played a major role in the preparation of the other elements that gradually filled the 7th period and in 2016 the last 4 elements – *nihonium, moscovium, tennesine and oganesson* – received their name from IUPAC and the current form of the periodic table, with its 118 elements, became complete for a time[6]. Various procedures can be used to prepare them, to mention just two of them. One is cold fusion, in which moderately heavy nuclei are blasted with heavier projectiles (particles). The other is to use a target of very heavy nuclei, which is blasted with lighter projectiles. Due to the difficult fusion and very short conversion half-lives, very advanced and expensive technologies are needed to prepare and determine their physico-chemical properties.

So far, we have dealt mainly with the history and properties of the elements, but we could also look at the issue at hand from a geographical point of view. Most elements were discovered in the UK, Sweden, Germany, France and the USA[7]. Scientists in five countries discovered or co-discovered almost a hundred of elements,

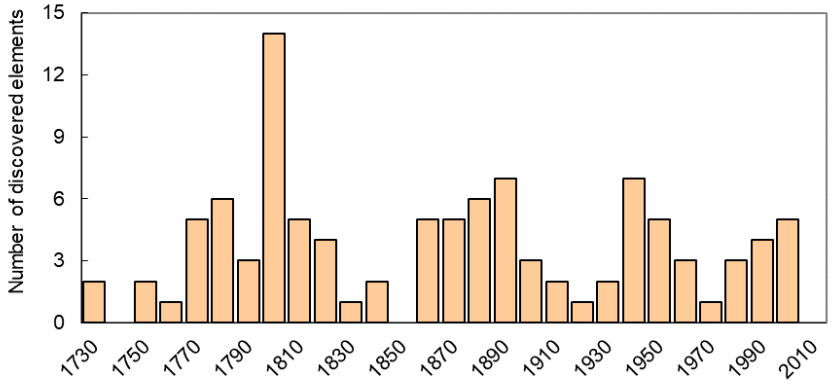

Fig. 5. **A number of elements discovered in the decades within 1730 and 2010**

Table I
Examples of successful and unsuccessful Presl's Czech element name proposals

Successful names and symbols		Unsuccessful names and symbols	
Suggested	Current	Suggested	Current
Vodík (V)	Vodík (H)	Solík (Sl)	Chlor (Cl)
Uhlík (U)	Uhlík (C)	Kostík (Ko)	Fosfor (P)
Dusík (D)	Dusík (N)	Platík (Pl)	Platina (Pt)
Kyslík (K)	Kyslík (O)	Strontík (Sr)	Stroncium (Sr)
Vápník (Vp)	Vápník (Ca)	Paladík (Pd)	Paladium (Pd)

which raises a number of questions: why were scientists in these countries so successful? Were the available natural resources, the economic situation of the country, or modern technology involved in their success?

Biology has not yet been mentioned among the natural sciences. It overlaps a lot with biochemistry. The terms macrobiogenic, microbiogenic elements and their compounds are common in both disciplines. Our world operates on a four-stranded carbon. Is it possible that silicon will take over its role in the future[8]? Scientists are dedicated to find the answer to this question, as well as they are strive to prepare new elements to open up the 8th period[6,9].

Let us now move on the map to the lands of the Czech Crown in the first half of the 19th century, where national revivalists tried to raise the Czech language to the level of the language of an educated society and, in connection with this, to boost Czech nationalism. Today, however, we will not deal with Dobrovský or Palacký, but we will look at the contribution of Jan Svatopluk Presl. Although originally graduated physician, he focused on a career in science. He named many minerals, plants, animals, and especially chemical elements! Examples of his successful and unsuccessful suggestions for element names and their symbols are listed in Table I. Gradually, Presl's successful names acquired international trademarks. Let's stop by the suggestions of the "*salt*" for chlorine and the "*bone*" for phosphorus[10]. Well, tell me, isn't it worth mentioning this cute little curiosity in Czech classes? As you can see from the proposed names, they were based on their representation in table salt and bones, respectively. And last but not least, there are a number of inspiring books interconnecting notable chemists to their journey in fiction. Mention must be made of *Mendeleev's Dream: The Quest for the Elements* (London: Hamish Hamilton, 2000) by Paul Strathern, or the earlier published book *Tvrdohlavá Marie (Stubborn Mary)* (1947) by Antonín Zhoř, the Czech writer.

And how to sum up the presented topic with the many questions asked? It is now up to us, teachers, in particular to think again about how we introduce the periodic table to our pupils and how we work with it. Whether the first experience of the pupils will be "*we must learn the signs of the elements by heart,*" or whether we will give them the opportunity and space for each pupil to find in it what is close to his/her heart, the opportunity to approach it comprehensively and from different perspectives. And, of course, we will gradually come to the chemical rules and natural relations hidden in it and we will unravel them together. Last but not least, this comprehensive approach requires cooperation between teachers of individual subjects, which is one of the areas that deserves improvement in Czech education.

I believe that the Periodic Table of Elements has been presented in an unconventional perspective on the occasion of its anniversary, its birthday, and has been given a new coat, and therefore I have no choice but to conclude by wishing it "*Happy Birthday, our useful helper!*"

REFERENCES

1. https://www.iypt2019.org/, downloaded 20. 1. 2019.
2. Mendeleev D. I.: *Osnovy khimii*. Izdatel'stvo akademii nauk SSSR, Moskva-Leningrad 1949.
3. Jockenhövel A. (ed.): *Dějiny světa 1: globální dějiny od počátků do 21. století*. Vyšehrad, Praha 2012.
4. Mokrejšová O.: *Moderní výuka chemie*. Triton, Praha 2009.
5. Atanassova M., Angelov R.: Bulg. J. Sci. Educ. *23(2)*, 275 (2014).
6. Hofmann S., Dmitriev S. N., Fahlander C., Gates J. M., Roberto J. B., Sakai H.: Pure Appl. Chem. *90 (11)*, 1773 (2018).
7. Scerri E. R.: *The Periodic Table. Its Story and Its Significance*. Oxford University Press, Oxford 2007.
8. Kan S. B. J., Lewis R. D., Chen K., Arnold F. H.: Science. *354(6315)*, 1048 (2016).
9. Hofmann S. a 36 co-authors: Eur. Phys. J. A *52(6)*, 180 (2016).
10. Canov M: http://canov.jergym.cz/objevite/objevite/tabulka_2.html, downloaded 23. 1. 2019.

Abstract

The United Nations proclaimed 2019 the international year of the periodic table of chemical elements. The paper presents the work of Dmitry I. Mendeleyev, which resulted in the periodic law and in the compilation of elements into the table in the form we use today. The history of the discovery of the elements is briefly discussed, and the interrelationship of chemistry with history, geography, physics, biology, and literature, including particular ideas for classes, is discussed in context.