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Editorial

The Periodic System, a History of Shaping and Sharing

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By now, everyone knows that 2019 has been dedicated to the International Year of the Periodic Table of the chemical elements (IYPT) by UNESCO. At the very least, this is true for the chemical community and science teachers and popularizers at large. On many occasions during this year, historical accounts have been provided by specialists and profane alike. The year 2019 was chosen precisely because it corresponds to the 150th anniversary of the first publication of a classification of the then known elements by Dmitrii Ivanovitch Mendeleev (transcribed from the Russian as Dmítriy Ivánovich Mendeléyev), a classification he ended up calling a periodic system when publishing it. He devised the system while he was working on a textbook of chemistry – the famous *Principles of Chemistry* (two volumes, 1868–1870) –, but immediately recognized the importance of what he had just sketched and published a separate one-sheet comprising the first "periodic table" with the title *An Attempt at a system of elements based on their atomic weights and chemical similarities* on March 6, 1869 (or 17 February in the Julian calendar as written on the sheet).[1]

Two features of what we have just outlined call for our attention. First, Mendeleev spoke and wrote about a periodic system (and later a periodic law) and not about a periodic *table*. Indeed Mendeleev's system is often referred to as a *classification* of the elements, and in many cases the periodic system was indeed first received as a classification by many of Mendeleev's contemporaries and successors. This is however not how Mendeleev viewed it. Second, the system emerged in a teaching context, even though Mendeleev published it separately from his textbook and continued publishing on it as

[1] Mendeleev rushed the publication of that separate sheet all the while he asked his colleague Nikolai Alexandrovich Menshutkin to read his paper to the Russian Chemical Society on 18 March 1869 (6 March Julian calendar). It was published as a few months after as "Sootnoshenie svoistv s atom s atomnym vesom elementov" ("The relations between the properties of the elements and their atomic weights"). Zhurnal Russkogo Khmicheskogo Obshchestva (Journal of the Russian Chemical Society). 1 (1869) 2/360-77.

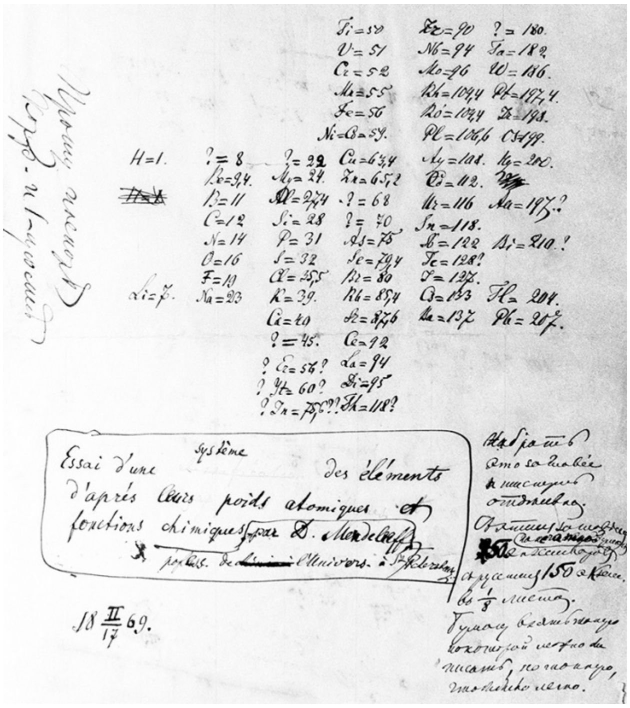

Figure. 1. The hand-written copy of the "Attempt" that would be published under the title "Attempt at a system of elements based on their atomic weights and chemical similarity" in both Russian and French, and kept at the Mendeleev Museum and Archives, Saint Petersburg State University, Saint Petersburg, Russia.

a research topic in itself, in parallel with the successive editions of his Principles of Chemistry.[2] To this day, the pedagogical use of the periodic system is still preeminent, as it is hard to imagine a lecture hall or a textbook in chemistry (or science) that would not feature a representation of the periodic system.

Let us first deal with the issue of nomenclature. This special issue uses the periodic *system* rather than *table*, which is a deliberate choice. There are thousands of periodic tables, according to Mark Leach who keeps a comprehensive database of periodic tables. His website provides a large variety of representations of the periodic system, most of them in two dimensions.[3] They come in many shapes, inner organizations and colors, and have evolved alongside new understandings of matter and the inner structure of atoms over the course of 150 years. Mendeleev himself designed and published several versions, demonstrating that what lied at the core of his thought was not the periodic *table*, even though it was presented in that form, but a *system* from which he inferred his periodic *law*. This is very clear from the title of his March 1869 publication mentioned and illustrated above. He perceived it as a natural law, which could be used to deduce the existence of elements and foresee their properties, not just describe existing knowledge. His trust in this law was such that it enabled him to predict correctly three elements that were discovered within less than 20 years of his initial statement. But his conviction also led him to failed predictions and errors of appreciation in the wake of new discoveries such as the noble gases or the phenomenon of radioactivity. To Mendeleev, if the system derived from the periodic law did not have space for an element, then this element could simply not exist. This is how he reacted when the news about the discovery of argon was announced before accepting a whole new group, the noble gases.[4]

While the distinction between table, system, classification or law might seem more of theoretical interest than anything else, these different conceptions of periodicity in relation to classifying chemical elements will be discussed in some of the contributions to this issue. That such distinctions are relevant and important will be demonstrated in the contributions dedicated to the response to the periodic system. Indeed, the appropriation process of the iconic tool that the periodic system is for chemistry, and its different shapes since its initial publication, do explicitly refer to a spectrum of conceptual objects, ranging from a mere classification to a system to a law of nature, including tables and charts that adorn textbooks or classrooms. Depending on which object is used or referred to, the reception is different and belongs to a different context of use.

This leads us to the second point. As mentioned earlier the teaching context was crucial from the start. It is within the context of teaching that the system emerged as a new tool, and it is also in this context that the appropriation process really took place. For a long time, historical accounts of the development of this seminal idea and the scientific icon have been limited to the traditional succession of chapters devoted to the questions of forerunners, co-discoverers (including the delicate question of priority), successful predictions, rearrangements according to atomic numbers instead of the atomic weights, and alongside atomic, subatomic and quantum interpretations. The discovery of new elements is often discussed as well, as is the question of the bounda-

[2] Van Spronsen, J. W. (1969). The Periodic System of Chemical Elements: A History of the First Hundred Years (Elsevier, Amsterdam, London and New York, NY; Scerri, E. R. (2007). The Periodic Table: Its Story and its Significance (Oxford University Press, Oxford) and Gordin, M. D. (2004). A Well-Ordered Thing: Dmitrii Mendeleev and the Shadow of the Periodic Table (Basic Books, New York, NY).

[3] https://www.meta-synthesis.com/webbook/35_pt/pt_database.php?Button=All

[4] See for instance: Giunta, C. (2001). Argon and the Periodic System: the Piece that would not fit. Foundations of Chemistry. 3. 105-128.

ries between chemistry and physics. For instance, both Van Spronsen and Scerri mentioned above use that organisation in their table of contents. Such traditional narratives, consciously or not, stress Mendeleev's genius, as if he were a prophet, able to devise a classification/system while atoms were still not accepted entities for chemists. As a result, the success of the periodic system often appears as a natural consequence of it being "correct".

When taking a closer look though, it appears that in many countries and institutions, periodic tables appeared rather late – which is hard to grasp given the position the system holds in today's chemistry. The question of "being correct" has a different meaning in teaching; teachers adopt what is helpful and efficient. Thus explaining the dissemination of the periodic system/table/classification in chemical education is crucial to understand its success and how it has become the icon we all recognize today.

A few years ago, a collective work edited by Masanori Kaji, Helge Kragh and Gabor Pallo was devoted to the first responses to the periodic system demonstrating the diversity of appropriation processes across the world, by offering case studies for several countries, some of which had not been studied before.[5] This built on a contribution by Stephen Brush which was influential even though limited to the mention of the periodic system or the mere inclusion of a table in textbooks, and had already pointed at some delay for the acceptance of Mendeleev's and Meyer's initial ideas.[6]

In this special issue, we have deliberately left aside the questions of priority, the discussion about predictions, and adaptations or rearrangements of the system to focus on *the process of how the periodic system became a shared universal tool for chemistry and science*. We envision this process as dynamic, and active, and we claim that this process was exactly so right from the very beginning when Mendeleev, Meyer and others published and discussed the periodic system and the periodic law. In fact, the periodic system published by Mendeleev in March 1869 is *not* the one we use today, as it was shaped in the following ten years by a succession of additions, changes and improvements that were the result of ongoing discussions with the community and constant interactions with teaching practice, as much as the outcome of a few men's solitary train of thoughts. The process continued all over the last 150 years. In the same way, when the periodic system eventually was adopted as a teaching device, this came most of the time as a result of a process of appropriation during which teachers, chemists and students shaped their own understanding and sometimes invented their own version. This is precisely why there are (and will be) so many periodic tables around: for a concept to become universal it has to be plastic enough to accommodate personal appropriation. Interestingly history becomes a part of how this tool is incorporated and legitimized in the textbooks and teaching practice. Even in science texts that leave very little place to the historical development of the chemical sciences, the discovery of the periodic system (or, quite often the periodic *table*) is mentioned as well as its discoverer(s). In a weird way this mention often smoothens or ignores the appropriation process, in a manner that negates the historical evidence and defaces the nature of science.

The history of shaping and sharing of the periodic system is approached in this special issue in three acts.

The first three contributions illustrate how the periodic system emerges and is shaped through the context of teaching chemistry. The contribution "Julius Lothar (von) Meyer (1830-1895) and the Periodic System" by Gisela Boeck provides insight into the development of Lothar Meyer's thought on a periodic system of the elements while he was devising the successive editions of his chemistry textbook from 1864 onwards. The wide variety of responses to the periodic system in Portugal analyzed by Isabel Malaquias and João A. B. P. Oliveira in the "Shaping the Periodic Classification in Portugal through (text)books and charts" provides a good example of how reception is linked to the different contexts of use. "The St Andrews Periodic Table Wallchart and its Use in Teaching" by Alan Aitken and M. Pilar Gil shows how a precious wall chart acquired in 1888 was used, getting us one step closer to the fine grain process of appropriation of the periodic system which is often hard to track.

The following two contributions analyze the way the history of the periodic system is presented in textbooks and how this kind of history shapes not only the central place of the periodic system in the teaching but also conveys something about the way chemistry developed. In "The Periodic System and the Nature of Science: The History of the Periodic System in Spanish and Norwegian Secondary School Textbooks", Luis Moreno Martinez and Annette Lykknes underline how the brief historical presentation of the periodic system in many textbooks affects the underlying teaching of the nature of chemistry and its history. Gebrekidan Mebrahtu Tesfamariam and Mengesha Ayene make the same assessment for Ethiopian chemistry textbooks for the sec-

[5] Kaji, M., Kragh, H. and Palló, G., eds. (2015). Early Responses to the Periodic System (Oxford University Press, Oxford).

[6] Brush, S. (1996). The reception of Mendeleev's periodic law in America and Britain. Isis, 87(4). 595–628.

ondary schools as they pose the question “Are History Aspects Related to the Periodic Table Considered in Ethiopian Secondary School Chemistry Textbooks?”.

The periodic system is alive and well, and its versatility and continuing evolution represents a challenge to the present and future sharing of this universal tool of chemistry, a challenge which lies at the core of the last three contributions. The attempts and so far limited success at standardization by the International Union of Pure and Applied Chemistry are described in “Order From Confusion: International Chemical Standardization and the Elements, 1947-1990” by Ann Robinson. This variety has its advantages. For instance, Alfio Zambon shows in his contribution “Periodicity Trees as a Secondary Criterion of Periodic Classification: Its Implications for Science Teaching and Communication” how a specific design, the periodicity tree he has devised, opens the way to a more chemical approach to the teaching of the periodic system. Along the same line, in “Compounds Bring Back Chemistry to the System of Chemical Elements”, Guillermo Restrepo reconstructs the 1869 system on the basis of computer analysis of chemical knowledge, and the use of contemporary databases yield other systems or groupings of elements classification according to their similarities. These provide a less physically laden approach to the periodic system that is nowadays usually explained in quantum mechanical, or even relativistic terms, ignoring the chemistry behind the making of the periodic system 150 years ago.

The result of a history of shaping and sharing, the periodic system will continue to evolve and its plasticity will no doubt continue to serve as one of its core values. As Professor Emeritus Pekka Pyykkö (University of Helsinki) expressed it during several talks along the IYPT: “It is a human right to make your own Periodic Table. Don’t let anyone take that right from you”.[7]

[7] These views were expressed a.o. during P. Pyykkö’s Lecture at the Mendeleev-150 conference in Saint Petersburg, Russia, and confirmed to the authors through a private communication, October 14, 2019.