Post Mendeleevian Evolution of the Periodic Table

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Periodic Round Table

We are here in the centenary of the death of Mendeleev, whose life defines the epoch of the Periodic Table. To his memory we respectfully dedicate this, our plan to revitalize his invention, the Periodic Table.

Since Mendeleev's death in 1907, the only substantive changes in the Table have been the insertion of new elements; most fall into the eighth period with another seven in the main body of the Table, but only three of these are stable non-radioactive species. The quantum chemical results of Niels Bohr came along early in the century elucidating the electronic configurations of the atoms, explaining a great deal about what made the Periodic Table periodic. By mid century when Seaborg proposed an actinide series to parallel the lanthanide series, including a number of the new transuranium elements, the official Table we now have was essentially in place. It has not changed fundamentally since that time.

In my previous paper "An Eight-period Table for the 21st Century" (1) I discussed the evolution of the 8-period concept and some of the people who have worked toward the goal of transforming the Periodic Table in this fashion. Since 2001, I have changed my terminology to agree with that of other writers: the 8-period table is now to be called the left-step table. This is a phrase coined by physical chemist Henry Bent, who proposed it back in the 80's, and it allows for the expansion of the table into periods beyond the eighth—a critical area of future development for the Periodic Table. Since my paper appeared in a subscription-only online journal that many may not have seen, I will briefly summarize it before going forward.

The left-step table originated in 1928 with Charles Janet, a retired French scientist of many facets (2). It is a direct application of the then recent work of Niels Bohr on quantum principles to the graphic depiction of the Periodic Table. Among exponents of the left-step system since that time was Edward Mazurs, whose book "Graphic Representations of the Periodic System" (3) reviews the many versions of the Table in the world literature prior to 1975 and makes the case for adopting the left-step system of Janet. He also suggests a possible three-dimensional expansion of that system. At about the same time van Spronsen (4) published a more mainstream overview of the Periodic Table and came to similar conclusions involving the reassignment of helium. Most recently, Eric Scerri, a leading contemporary scholar of the Periodic Table, has published a thorough and up to date treatment of the subject in his well-received volume "The Periodic Table: Its Story and Significance" (5). Scerri's comprehensive work cites many other fine commentaries, like those of John Emsley, P.W. Atkins, etc. The subject of the Periodic Table has not been lacking in either popular or academic attention in the last ten years. It has been frequently brought up in the journals, Chemistry International and The Journal of Chemical Education, and it has proliferated on the internet. Despite all the attention, the official table remains essentially the same. Most scientists are not even aware of the existence of alternative periodic tables.

Would Mendeleev be pleased that his work has apparently evolved so little, while so much else in science has changed? Perhaps not; it is quite likely that he would have focused on the unsatisfactory aspects of the Table, and reconfigured it to demonstrate a higher level of order. So what are the troubling aspects of the Table as it is currently portrayed in its approved version? First, and most obvious is the "footnote" display of the lanthanide-actinides, or "f"-block elements. Present day knowledge and utilization of these elements implies that they are just as much a structural part of the Table as any other elements, and require their own dedicated space in the display. The second more difficult problem is establishing the correct relationship of the period one elements, hydrogen and helium, to the elements below them. This is the biggest obstacle toward arriving at "A Rational Periodic Table," and constitutes the core of this discussion.

It is proposed that hydrogen and helium should be considered in terms of the role they are now known to play in the big bang cosmology and stellar nucleosynthesis. In this realm hydrogen and helium are the parent elements from which the higher elements are synthesized. This role of hydrogen and helium, as progenitor elements, partly serves to justify their placement in a first period of 1s elements vertically separated from the subsequent periods by a space. Once this change is made we proceed easily to the left-step table and its three-dimensional counterpart, the Periodic Round Table. This version of the Periodic Table, conceived 30 years ago, received a U.S. patent in 1980 and is available from, among others, the ACS Education Division. (A similar product called Elementree, which does not reposition helium or demarcate eight periods, has also been available commercially for the last few years).

In chapter 10 of his book Scerri examines the issue of "the one best periodic table" and concludes that the left-step table, with its regular construction and its adherence to the Periodic Law (n +"l "= P), fills that role. Seemingly he has the support of numerous other writers who have also agreed with aspects of the left-step movement in the past. Never the less, H.D.Kaesz, a prominent IUPAC committee member, dismisses the left-step table in a review of Scerri's book in the IUPAC journal, Chemistry International (6), describing it as of interest only to "specialists" and declaring that "it is more important to emphasize similarities in chemical properties than in… electronic arrangements.” Except for the reassignment of helium, there are in fact no electronic rearrangements between the IUPAC table and its left-step counterpart. Though these tables might appear radically different, they are in fact topographically equivalent. Recently Scerri has pronounced on the web (7) that he has shifted his “allegiance… from the left-step table to this one”, and depicts a new table of his own devising, which represents a complete retreat from the left-step movement.

Why would this leading scholar and advocate of Periodic Table reform withdraw endorsement of the left-step table and leave the old medium-long still in place? Perhaps the answer to this question lies in a place outside science where the operative forces are in the realms of politics, psychology and tradition.

The structure of the Periodic Table is directly or indirectly under the aegis of IUPAC whose governance has extended back to 1919. Re-drawing the Periodic Table means getting approval through a process governed by IUPAC. This may be a formidable task, since acting on a legislative initiative in a parliamentary body of several thousand scholars is at best a long drawn out process. Previous Periodic Table changes involving smaller technical issues took many years to resolve; in any case the IUPAC process has never been receptive to Periodic Table evolution. This could well be the first time that scientific theory is validated through the legislative process.

The Periodic Table does not have a “real” physical description like the three dimensional structure of a molecule. Physical entities like molecules, have tangible forms which have been realized through instrumental analyses, giving them a physical existence. In contrast, the Periodic Table exists entirely as a mental construct; it is the sum expression of centuries of experiment and theorizing about relationships among the chemical elements. Assessing these relationships is actually a fitting game whose rules are subject to the predilections of chemists, rather than to the protocols of crystallographic analysis, for instance. It would seem that eventually the process of paradigm shift would take over when facts become overwhelming, but here the tools of consensus are of a psychological nature.

The Periodic Table has been the icon of chemical knowledge since its inception. Learning the Periodic Table can be thought of as synonymous with an initiation into the rites of chemistry. All of us have that in common - one cannot be a chemist without fixing the Periodic Table into the center of one’s mental landscape. Of course all of the sciences share this access to the Periodic Table, but it is the chemists who most deeply feel the ownership of the text. Naturally the attitude of most chemists to the Periodic Table is very dogmatic. The Periodic Table as it was learned in high school becomes a kind of sacred text; alteration and amendment of that text might feel uncomfortable.

Why change the Periodic Table?

Science may adopt a new theory or hypothesis if the new theory better explains the known facts than predecessor theories. Sometimes the new paradigm is readily accepted, other times resistance comes in the form of a strong backlash. In all cases the paradigm shift must be justified by large-scale benefits to the conceptual landscape; old mysteries are solved, disorder gives way to order, and new areas of research open up with the improved vision. Usually there is also a reductive benefit in the form of an improved mathematical formulation for the observed phenomena. Such was the impact of quantum theory on the understanding of the Periodic Table in the early twentieth century, for example, resulting in the numerical form of the Periodic Law, n + “l” = P.

Restructuring the Periodic Table according to the left-step method would most likely subtend a different kind of benefit, involving a comparatively minor rearrangement. This benefit is twofold: first, when we transform a somewhat shapeless and scattered display into a depiction that is mathematical and regular, we get a periodic table that does the same job as before, but expresses the beauty and symmetry of the relationships among elements. Second, we provide a rightful place for the new elements being discovered in heavy-element research programs around the world. Soon these programs will lead us to elements beyond 118, which is the highest number that can be accommodated by the medium-long system. Where will the “g” elements in the upcoming ninth period be displayed? Will we have to have another footnote? Recently G. Malli has published theoretical calculations for element 126, which lies well beyond the end of present tables (8). It is highly likely that the necessity of fitting in higher elements will be the decisive factor in moving IUPAC to take up the Periodic Table problem in earnest. This could well take many years. Meanwhile, yet another generation of students will be deprived the use of a Periodic Table that provides an elegant aesthetic solution for future additions as the Periodic Round Table does.

CONCLUSION

Were Mendeleev to return in 2007, what would he be most likely strike him as the difference between the official Periodic Table approved by IUPAC and the Periodic Table of say 1905? The answer is that while virtually all of science has moved forward in that hundred years, the basic structure of the Periodic Table Mendeleev last saw in 1907 remains unchanged. Yes, new elements have been discovered, but they have all been relegated to places dictated by the Mendeleevian display.

This presentation must conclude by proposing a course of group action in order to move forward with the upgrading of the Periodic Table under IUPAC. The goal is to enlist member delegates to study and approve the advancement of the Periodic Table. I am proposing that we create a web-based group to work toward restructuring the Periodic Table within the IUPAC framework. Perhaps if a group of scientists committed to Periodic Table reform work together on this we will see positive results in our lifetime.

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