A Philosopher's View on the Periodic Table of the Elements and Its Significance

Interview with Eric Scerri

By Svetla Baykoucheva
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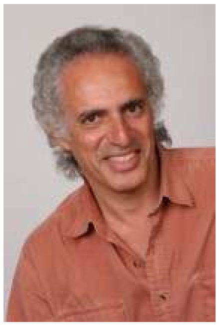

"Imagine the sight of the snow under a ski chairlift on the first sunny day after a storm, when untracked powder tempts you from below. You know that no matter what, once you hit the snow, it's going to be a great day. Some runs will be steep and full of bumps, some will be easy cruisers, and some will be tricky routes through trees. But even if you take the occasional wrong turn, most of the day will be wonderfully rewarding."
-- Lisa Randall (2006) Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions, p. 8.

Eric Scerri is originally from Malta. He obtained all his degrees in the UK. His bachelors and masters degrees were in chemistry from the universities of London and Southampton. His PhD was in history and philosophy of science from Kings College, London. He went to the US as a postdoctoral fellow at Caltech fifteen years ago and has remained in the US ever since. For the past 10 years he has been teaching chemistry and philosophy of science at the University of California at Los Angeles. Scerri is one of the founders of the field of philosophy of chemistry as well as the founder and editor of the journal Foundations of Chemistry, now in its eleventh year of publication. Dr. Scerri has written what reviewers have called "the definitive book on the periodic table, " The Periodic Table: Its Story and Its Significance. He is also the author of two books with Imperial College Press in London. He is currently writing two more books with Oxford University Press. Scerri is also the author of over 100 journal articles in chemistry, chemical education and history and philosophy of science. In recent years he is turning increasingly towards working in the TV and radio media and to presenting his work to the general public.

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Svetla Baykoucheva: In an interview for Nature Chymist, a Nature Chemistry blog, when asked which historical figure you would like to have dinner with, you said this would be Dmitrii Mendeleev (http://blogs.nature.com/thescepticalchymist/2008/01/reactions_eric_scerri.html). In your book, out of 10 chapters two are devoted to Mendeleev. What is it about him that has struck you most? If you could really have dinner with him, what questions would you ask him? Eric Scerri: I am struck with the fact that he was so far ahead of the other chemists who groped their way towards the periodic table. I am also amazed by the confidence with which he believed in the periodic law which he formulated and the even greater confidence with which he predicted the existence of new elements. Allow me to quote from his paper which appeared in German in 1871, just two years after his initial periodic table of 1869: ?...we can see, by referring to tables I and II, in which the periodic relations are shown, that many elements are missing, and we can confidently predict their discovery. I am therefore going to describe the properties of several as yet undiscovered elements. In this way I hope to demonstrate in an accurate and perfectly clear manner the adequacy of the law, although confirmation of these proofs is reserved for the future.

Eric Scerri: I would ask him whether he really had not seen the rudimentary periodic tables of De Chancourtois, Newlands and Lothar Meyer, before publishing his own table, as he later claimed. I would also ask him about his philosophical views on the nature of =elements' as this has become a much discussed topic within contemporary philosophy of chemistry. Mendeleev certainly had profound views on the issue and referred to them even in the first of the two volumes of the first edition of his famous book. He did this even before formulating the periodic table, which he did while considering how to make a transition to the remaining elements that he wanted to discuss after those in volume one.

Dmitrii Mendeleev
AIP Emilio Segre Visual Archives

SB: An excellent book on Mendeleev was written by Michael Gordin (Gordin, M.D. (2004) A Well-ordered Thing: Dmitrii Mendeleev and the Shadow of the Periodic Table. Basic Books, New York). Your book is the most comprehensive work entirely devoted to the periodic table. I can admit that I read it like a novel. How did you do the research for it and what is generally your way of writing? What resources did you use?

ES: Thanks very much for saying so. It is the single most intensive piece of work I have ever done and it involved a fair share of trials and tribulations. The research for the book stretches back for a period of about twenty years to my PhD thesis in history and philosophy of science, which was on the reduction of chemistry to physics. But rather than trying to deal with the whole of chemistry, I decided to concentrate on one very central aspect of chemistry, which embodies so much chemical knowledge and information—the Periodic Table—and to ask how, or to what extent, it has been reduced to physics, in general, and to quantum mechanics, in particular. As for my sources, I would like to think that I have read everything published on the subject, in many cases a number of times. The other =source,' of inspiration at least, goes back to my childhood and the fact that I have always admired the orderliness and compactness of the periodic table, the feeling that all of chemistry was somehow contained in this elegant chart.

SB: I read somewhere that you had been involved with some TV productions. What did you do for TV and what are the projects you have been working on now? What is in your future plans?

ES: I have been a consultant and interviewee in a couple of series on the periodic table, one in the UK and the other one in the US, both of which are yet to air. I was also part of a one-hour radio show made by the Canadian Broadcasting Corporation, CBC, called ?The Music of Matter.? It consisted of extended interviews with John Emsley, Oliver Sacks and with me on the subject of the periodic table. I am very interested in getting more involved in this kind of work, perhaps even on the production side, and I invite anyone reading this interview to get in touch with offers or suggestions. As you know there is far too little on chemistry in popular science TV and radio, and of course not enough popular science books centered on chemistry. I hope to do my bit to redress this imbalance as much as possible.

SB: You are evidently very interested in predictions in chemistry, in general, and in the development of the periodic system, in particular. You have a sub-chapter in your book, ?Mendeleev's less successful predictions.? How do philosophers of science view the failed predictions of scientists, and how are such predictions treated, especially if they have never been published? Should they be counted as failures?

ES: Thank you for raising the issue of predictions because I want to clear the record on this. When an article describing my book appeared in the New York Times, the author claimed that I was trying to minimize the achievements of Mendeleev and was claiming that many others had discovered the periodic table before him, especially the Frenchman De Chancourtois. In fact I have the utmost respect for Mendeleev's work, although a historian is obliged to lay-out the record of discoveries as he sees it. My reason for devoting a great deal of attention to predictions is because of a long-standing debate in the philosophy of science which seeks to establish whether scientific theories and developments are accepted mainly because of successful novel predictions or perhaps for their successful accommodations of already known facts.

One of the pioneers in this question has been Professor Stephen Brush who you may have known before he recently retired from the University of Maryland at College Park. Brush argued that in a number of key theories in physics, for example, it was successful accommodation of already known phenomena that was in fact more decisive in the acceptance of the theories in question. For example, he and others have claimed that Einstein's theory of general relativity was primarily accepted for correctly explaining the long-known advance of the perihelion of the planet Mercury and not for the dramatic and successful prediction that Einstein made of the bending of starlight by massive gravitational objects. But when it came to chemistry, Brush appeared to vacillate and claimed that this was one case in which successful predictions had indeed been more decisive than accommodation of already known elements in the acceptance of the periodic table. I wrote a long paper with the philosopher John Worrall in which we argued that accommodation of elements by Mendeleev's table may also have been more decisive, or at least as decisive, as the predictions in the acceptance of the periodic system. This is why we examined his predictions so closely, including his failed predictions. The point is that if predictions had been regarded as being so decisive, one would expect the failed predictions would have counted against the acceptance of the periodic table. But there were several failed predictions and yet the system was accepted, perhaps because the outcome of predictions was not all that crucial contrary to the popular accounts.

SB: With my previous question, I wanted to find out whether, when talking about Mendeleev's unsuccessful predictions in your book and later in one of your papers (Scerri, E. R. (2008) The past and future of the periodic table. American Scientist 96 (1), 52-58), you have counted as his failures even predictions that had not been published officially. Making predictions and having hypotheses is what scientists do all the time. This is how science is done—speculate and prove whether you were right. Should such failed predictions, if they have not been published officially, be taken into account when evaluating how successful a scientist has been in making predictions?

ES: I agree with you that unpublished predictions should not count in the assessment of a scientist's work. When I claimed in my book that nine out of eighteen predictions made by Mendeleev had been successful, I was referring to predictions that he actually published at one time or another. This includes his prediction of two elements that he believed to be lighter than hydrogen and his prediction of ether as an element, which he made in 1905 a couple of years before he passed away. Some authors regard these predictions as the speculative outpourings of an elderly and established scientist with nothing to lose and I suppose one must agree with that, although these ideas appear to have been well thought-out and appeared in a short-book form.

SB: Has Mendeleev betrayed some of his predictions that he based on the atomic weight of the elements for the purpose of accommodating their chemistry, and why did he do that (for example, putting tellurium (Te) before iodine (I)?

ES: This is another very subtle and interesting issue. You are referring to the pair-reversals. In the case of Te and I, adhering to the then known atomic weights should have placed these elements in chemically incorrect groups since iodine had a lower atomic weight. Mendeleev, and incidentally, Newlands and Odling before him, all placed Te before I because of the chemical similarities which each of these elements had shown with the oxygen group and the halogens respectively. This much is true, but Mendeleev did not really betray his belief that the ordering principle lays in using atomic weight. Instead, he repeatedly insisted that either the weight of tellurium or that of iodine had been incorrectly determined. Contrary to the popular account, we might say he did not simply put more emphasis on chemical properties, but instead maintained that the atomic weight ordering was the exceptionless criterion for ordering the elements. But throughout his life, the repeated attempts that he made to establish that Te has a lower atomic weight have failed. Of course the correct ordering principle is atomic number, and not weight, but this would only emerge in the second decade of the 20th century following the work of van den Broek and Moseley.

SB: The main theme in your book is the relationship between chemistry and physics and to what extent quantum mechanics explains the periodic system of elements. From the point of view of a philosopher of chemistry, can chemistry be reduced to physics?

ES: First let me say that I do not try to answer the =in principle' question of whether chemistry can be reduced to quantum mechanics. My emphasis has always been on the extent to which chemistry has in fact been reduced to quantum mechanics. After all, who really knows what is possible in principle or what might be possible via a future development in quantum mechanics? On the other hand, one can carefully examine whether present day quantum mechanics does a good job of explaining in a more fundamental manner chemical phenomena such as perhaps the form of the periodic table. I have claimed that although quantum mechanics gives a perfectly good ab initio explanation of the lengths of periods of elements it does not fully explain the precise order of shell filling which is summarized by the n + l or Madelung rule which is familiar to anyone who has studied college or even high school chemistry. And let me repeat—I am not claiming that such an explanation is not possible in principle but just that nobody has yet succeeded in deriving this rule from the general principles of quantum mechanics.

SB: How do scientists working in individual disciplines relate to and treat each other? Are there disciplines that are considered superior to other disciplines? When I was in college, I remember that physical chemists were kind of elite. I can admit that this might have played a role for me choosing to do a Master's degree in physical chemistry. I later spent most of my scientific career working in areas closer to organic chemistry (lipids and fatty acids).

ES: Yes I agree with you, physical chemists and even more so theoretical chemists consider themselves somehow superior to other specialists within chemistry. And theoretical physicists consider themselves even more superior. Some of this one-upmanship is perhaps inevitable since the more theoretical the discipline, or the more one moves towards physics, the more the scientist is operating at a more fundamental level. But more fundamental in the literal sense should not be mistaken to mean superior since work at the less fundamental levels is just as essential and in most cases remains indispensable. This is the paradox of reduction in all the sciences. We gain knowledge of larger objects in terms of their microscopic components and the way they are organized and yet the detailed knowledge must still be acquired by painstaking work at each of the appropriate levels in the scientific hierarchy.

SB: Another major theme that runs through your book concerns the nature of the element. This question has puzzled Mendeleev and has significantly influenced his views. I would like to quote something from your book: ?endeleev held a dual view on the nature of elements, where they could be regarded as unobservable basic substances and also as Lavoisier's simple substances at the same time. Mendeleev thus acknowledged one of the central mysteries running throughout the long history of chemistry, which is the question of how, if at all, the elements survive in the compounds they form when they are combined together. For example, how can it be claimed that a poisonous gray metal like sodium is still present when it combines with a green poisonous gas chlorine, given that the compound formed, sodium chloride, or common table salt, is white and not only nonpoisonous but also essential for life??How does the philosophy of chemistry deal with this question and what diverging views exist in this area?

ES: There is a sense in which the question you are alluding to now lies at the very heart of philosophy of chemistry. Let me use a well-worn example. When iron filings are mixed with sulfur, we obtain a physical mixture of two elements. But when sodium reacts with chlorine, we obtain a compound in which the component elements are not as easily recovered and also seem to have been radically transformed. To me the chemical change is far more magical and far more mysterious. Understanding such chemical changes requires its own philosophical approach. Mendeleev and others provided the beginnings of such an approach. We need to regard elements in two senses, or maybe even three senses. First there is the element as a simple substance such as grey sodium. Then there is the sodium, which is combined as in the case of sodium chloride. And thirdly there is what is common to both of these forms of the element. The third option has been called ?he element as a =asic substance'?, a somewhat unfortunate terminology in view of the unintended reference to acid-base properties. Mendeleev believed that it was this more fundamental, more philosophical sense of the elements that were represented on the periodic table and not the other two senses. This is not so hard to appreciate. For example, the halogens, as simple isolated substances, are rather different and they even display all three states of matter at room temperature. They are not grouped together because of their similarities as simple substances. On the other hand, their compounds with sodium, for instance, are all very similar. The properties of the combined elements appear to be more decisive. Philosophers of chemistry are currently trying to clarify these distinctions, especially given the centrality of the concept of =lement' in chemistry. There is a good deal of disagreement with some wanting to regard the most fundamental sense of element as metaphysical, others—as merely abstract— and so on.

SB: Although it took you seven years to finish this book, it has been on your mind for 20 years. Why is the periodic table philosophically important?

ES: Quite simply put the periodic table embodies the heart of chemistry and the relationships among the elements. It is by far the biggest idea in modern chemistry, equaled only by the notion of chemical bonding to which it is of course strongly related. The nature of the periodic table defies the usual ways in which scientific concepts are classified. It is not a theory or a model but, in a sense, it is just a representation and yet one that is capable of establishing far-reaching correlations. Attempts to explain the periodic table by people like Bohr and Pauli have produced important concepts and have helped to shape quantum mechanics itself. Instead of thinking that quantum mechanics explains the periodic table, I prefer to think of the periodic table as having helped to give birth to quantum mechanics.

SB: The development of the periodic table has involved interplay between theory and experiment. How have the philosophical deliberations of Mendeleev about the nature of the element influenced his predictions?

ES: This brings us back to the philosophical understanding of the concept of an =element‘. In my book, and some articles, I have claimed that Mendeleev‘s willingness to go beyond the facts, to make predictions and to correct the atomic weights of many elements, was based on his belief that the periodic system was primarily a classification of the elements in their more abstract and fundamental sense. Had he been more tied to the properties of the elements as simple substances, I don‘t believe that he would have been able to go beyond the known facts on so many occasions. He had a deeper appreciation of the nature of the elements than his competitors and, like all truly great scientists, he was as much a philosopher as a technical scientist.

SB: As you have mentioned in a recent article, through the years, many people have tried to create their own models of the periodic table. This somehow reminds me of a situation in France, where even today there are people who are proposing ideas about how to calculate the face of the circle. They send their ideas to the French Academy of Sciences, where each new proposal is registered (in the Archives of the Academy). You also have proposed your own version of the periodic table (Fig. 1), in which you have put H in the first column/group, together with the halogens. Did you do it this way because you consider the atomic weight to be more important than the chemical properties of the elements?

ES: Actually my proposal was based first of all on atomic numbers and secondly on the desire to create new atomic number triads. Triads using atomic weights provided what I have called the first hint that there were numerical regularities among the elements. Since atomic number is now known to be a superior ordering principle, it is worthwhile considering atomic number triads. If we place hydrogen above fluorine and chlorine, we obtain a new perfect atomic number triad in the sense that the atomic number of the middle element of these three, fluorine (9), is the exact average of the atomic numbers of hydrogen (1) added to that of chlorine (17). If hydrogen is left among the alkali metals where it most usually placed we have nowhere near to an atomic number triad H (1), Li (3) and Na (11). But I still have work to do in convincing the scientific community that atomic number triads are fundamental and not merely a form of numerology. I am in the process of publishing an article in which I argue that electronic structure is governed by the nucleus, which if true would strengthen the notion that atomic numbers and relations among them have a fundamental role to play in the question of the placement of elements in the periodic table.

SB: What are the hot areas of research in the philosophy of chemistry today?

ES: The question of reduction is still important as are the notions of natural kinds. Some of my colleagues are interested in whether chemical bonding should be regarded structurally or in a more realistic sense. There is also work being conducted on oscillating reactions, the philosophy of organic chemistry and of biochemistry. You can get some better idea by consulting copies of the journal Foundations of Chemistry which is now in its twelfth year of publication.

H	He	Li	Be											B	C	N	O
F	Ne	Na	Mg											Al	Si	P	S
Cl	Ar	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se
Br	Kr	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te
I	Xe	Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po
At	Rn	Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh
Uus	Uuo																
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb		
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No		

Figure 1. This version of Eric Scerri‘s Periodic Table places H with the halogens. The table was featured in an article in American Scientist (Scerri, E.R. The past and future of the periodic table. American Scientist 96(1), 2008, 52-58.

SB: In one of your papers you pondered on whether ?our reliance on the two-dimensional forms of the periodic table is due to the predominance, until recently, of the two-dimensional textbook page surface and the two-dimensional nature of the walls of lecture theaters?? And you were wondering whether, ?with the development of the new technologies, Mendeleev's famous icon might be transformed into something that even he might not recognize if he were here to see it? In her brilliantly written book, ?Warped passages: Unraveling the mysteries of the Universe's hidden dimensions, the theoretical physicist Lisa Randal talks about the possible existence of parallel universes, warped geometry, and an extra-dimensional world. How do you see the future development of the periodic table and the possible role that philosophy could play in it?

ES: I think that the most interesting question is whether it makes any sense to seek an optimal periodic table or whether most representations are ultimately just as worthwhile. I am a realist about chemical periodicity, that is to say I believe that the approximate recurrence of the elements after certain intervals is an objective fact of nature. It is not a convention that we impose on nature. Consequently, there is no question in my mind that some periodic tables are better than others and indeed that it is worth seeking an optimal table. I am also a little puzzled that many chemists, who usually espouse realist views on most scientific matters, often deny the notion of one best table. Let me stress that I don't mean what shape the periodic table should be presented in whether it be rectangular, circular, elliptical or pyramidal. I am referring to differences concerning the placement of certain troublesome elements such as hydrogen, helium. I cannot agree with textbook authors and periodic table designers who show hydrogen, or even hydrogen coupled with helium, alone hovering above the main body of the periodic table. This amounts to the claim that these two elements are not subject to the periodic law which I find distasteful. There is also a long-standing debate about whether group 3 should consist of Sc, Y, La, Ac or perhaps Sc, Y, Lu, Lr. I am in favor of the latter arrangement incidentally, again because of atomic number triads. Some of these topics do not involve technical scientific information but are to some extent meta-scientific. This is where philosophy of chemistry can play an active role. Thank you for allowing me to voice my views on my favorite topic.

Eric Scerri teaches chemistry as well as history & philosophy of science at UCLA
Books written by Scerri can be found on Amazon

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