International Journal of Innovation Scientific Research and Review
Vol. 06, Issue, 11, pp.7316-7321, November 2024
Available online at http://www.journalijisr.com
SJIF Impact Factor 2023: 6.599

ISSN: 2582-6131

Research Article

MENDELEEV'S PERIODIC LAW: IS IT A GENUINE SCIENTIFIC LAW?

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Received 09th September 2024; Accepted 10th October 2024; Published online 26th November 2024

ABSTRACT

The aim of this paper is to analyze and assess the validity of Mendeleev's Periodic Law as a scientific law and to gain understanding of its implications to the nature of science. Upon its entrenchment as a fundamental law in discovering the yet undiscovered elements starting 1875, the Periodic Law gained its reputation as a basic tool in the succeeding attempts to determine the existence of predicted elements. The high accuracy of its predictive nature following the establishment of the physicochemical data derived from the methods of Mendeleev on the periodicity of elements had resulted into a high confidence of its utility and its bold acceptance within the scientific community at the time. However, the Periodic Law was under scrutiny due to its lack of law-like character. By tracing the history of the Periodic Law, its subsequent accomplishments and the reactions of the scientific community and philosophers of science, it became apparent that this law lacks some merits of a scientific law. The rather dubious functionality of its predictive nature gave rise to skepticism because it does not possess the qualities of a scientific law, i.e., empirical proofs of its processes. Moreover, many of the first attempts of Mendeleev involved many errors which resulted into few more attempts in modifying the Periodic Table. Analysis of its nature indicated that the Periodic Law appeared to have a descriptive nature in contrast to the empirical nature of exact sciences such as Chemistry and Physics. Further analysis showed that it failed to express its functionality against the philosophical standards of a scientific law. Since some of its merits do not qualify in the realm of scientific laws, it is likely that the Periodic Law may violate the nature of science.

Keywords: Periodic Law; Scientific Law; Dmitriy Mendeleev; predictions; nature of science.

INTRODUCTION

The arrangement of the elements in the Periodic Table based on their atomic masses, and later on atomic number, had revolutionized the discovery of the predicted elements such as gallium in 1875, a component of lasers, and germanium in 1886, an essential constituent in the transistor industry (Powell, 2016). Such elemental arrangement is attributed to the periodicity within the Periodic Table, commonly known as the Periodic Law. This law had assisted the empirical investigations of certain scientists in identifying and categorizing the existing and newly-discovered elements. In light of this, the Periodic Law, as a basic unit of reference for the discovery of elements and in the subsequent construction of the modern Periodic Table, is an important scientific tool that must be critically analyzed and evaluated.

Exploring on the formative years of Mendeleev's work in formulating and utilizing the Periodic Law, analyzing the interactions and contributions of his contemporaries in the scientific community, and reflecting on the perspective of philosophers of science may give us a hint on the processes involved in the establishment of this law and provide enlightenment of its subsequent importance and consequences in the formation of the modern Periodic Table. How such law had predicted undiscovered elements eventually raised skepticism among scientists in the time of Mendeleev (Scerri & Worrall, 2001). Being doubtful of the Periodic law's predictive power, some scientists and philosophers of science had scrutinized its validity as a scientific law.

Thus, this paper is aimed at examining the validity of the Periodic Law in the realm of scientific laws; such laws are considered primary essential tools in explaining, analyzing, and even predicting scientific phenomena and processes (McComas, 2003). Moreover, this paper analyses and evaluates Mendeleev's conceptual methods in constructing the first few versions of the Periodic Table in reference to the tentativeness of establishing a final version of this table. The merits of the Periodic Law in predicting undiscovered elements and in the subsequent positioning of such elements in the Periodic Table will be contrasted to the nature of a scientific law. The main point that this paper navigates is whether the Periodic Law is able to qualify as a scientific law; such qualification will then be examined against its predictive nature in identifying undiscovered elements.

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Who is Dmitriy Ivanovich Mendeleev?

Dmitriy Ivanovich Mendeleev was born on February 8, 1834 in To bolsk, Russia. Raised in an affluent family, Mendeleev enjoyed the comfort of an excellent library and relished a rich interaction with political figures. Though terribly inclined with the languages, Mendeleev showed enthusiasm and excellence in natural sciences and mathematics (Babaev, 2009). Knowing that Mendeleev is a brilliant and promising student, his mother Maria Mendelevna planned to send him to Moscow for an exclusive university education. However, he was denied entry into the university because Moscow was not his birthplace and of his low esteem in classics. So, they continued searching until they reached St. Petersburg and finally found a place for him at the Chief Pedagogical Institute, the same institution where his father Ivan Pavlovich got his degree (Babaev, 2009; Gordin, 2002; Woods, 2010).

He started his career in teaching at Simferopol School (Woods, 2010). The school closed after a few weeks due to war, so he moved and taught natural science and mathematics at Odessa (Babaev, 2009). However, he was determined to embark in research works to obtain professorship in the university. Consequently, he applied for his magister degrees at St. Petersburg Imperial University where he was conferred two degrees in 1856. His magistrate theses about specific volumes and structure of silica compounds paved way for him to secure a docent position and then later Junior Lecturer in universities within St. Petersburg. Due to his brilliance, he was sent abroad for further studies; there he met Robert Bunsen at Heidelberg in 1859, and had the opportunity to attend the prestigious International Chemical Congress at Karlsruhein 1860 (Brush, 1996; Gordin, 2002; Woods, 2010). In this conference, Mendeleev was exposed to prominent scientists such as Lothar Meyer, Kekule, Erlenmeyer, Odling and Wurtz, and learned about their current scientific researches. The confusion about atomic weights was left unresolved during the conference. Later in 1864, Cannizaro, proposed a possible approach to solve such confusion based on the earlier concepts of Avogadro (Gordin, 2002). Cannizaro was credited as the major influence to Mendeleev's proposition of the Periodic Law that was later used to arrange over 60 elements known at that time.

In the early 1860's until the onset of 1870's, Mendeleev became active in propelling the role of the Periodic Law in predicting undiscovered elements. During those years, Mendeleev had predicted the properties of some elements; the most prominent, which were later discovered independently by other scientists, were gallium (1875 by Paul-Emile Lecoq de Boisbaudran), scandium (1879 Lars Frederik Nilson), and germanium (1886 by Clemens Winkler). The success of predicting these elements had elevated Mendeleev's prominence in the field of chemical investigations and entrenched the Periodic Law as a significant tool for discovering new elements.

MENDELEEV AND THE PERIODIC LAW

Mendeleev was not the pioneer in examining the periodicity of elements. In Western Europe, there was a growing interest in attempting to explain the trends among the known elements. Among them were the French geologist Beguyer de Chancourtois, British chemist John Newlands, and German chemist Lothar Meyer (Brush, 1996; Woods, 2010). Newlands' *Law of Octaves* was met with criticism due to an irregularity in the arrangement of elements based on atomic weight and an ordinal number written beside the element's symbol. Such arrangement resulted to the omission of the noble gases and the subsequent arrangement of the elements in rows and not in groups. In addition, Meyer's paper on periodicity a year after Mendeleev's publication of the same context, illustrated the arrangement of elements in a graphical form using atomic volume and atomic weight. Further, de Chancourtois presented helix-type illustrations of the elemental arrangements (Hettema & Kuipers, 1988). Of these various representations, it is clear that the conception of the Periodic Law involves remarkable differences and competing ideas. With this, the establishment of the Periodic Law has been crafted independently having most of its claims from Mendeleev as the main author (Brush, 1996). This claim was noted by Mendeleev himself when he exclaimed,

> …I consider it necessary to state… that I made use of previous researches of Gladstone, Dumas, Pettenkofer… but I was not acquainted with the work of De Chancourtios… in France, of J Newlands in England although certain germs of the periodic law are to be seen in those works (Woods, 2010 p. 175).

It was in March 1869 that Mendeleev began to extensively work on the formulation of the Periodic Law. Apparently, Mendeleev's first attempts in constructing the Periodic Table based on periodicity demonstrated incorrect and inaccurate methods. According to Woods (2010), the pre-1945 Periodic Table had missing parts, just like a jigsaw puzzle, and Mendeleev managed to place these elements in their positions in just three days. Back then, it was easy for Mendeleev to arrange the missing elements because they are found in just two clusters. The accuracy of such positioning required no scientific reasoning and it seemed to lack any scientific process. Indeed, a mere rearrangement of these elements does not support any successful prediction nor correct placement of elements considering that their characteristics must coincide with other elements possessing the same chemical properties.

Some of these mistakes, Woods (2010) noted, include the arrangement of elements having the same valency in a row, inclusion of hydrogen among transition metals such as silver and copper, separation of most transition metals from them main-group elements through sets of three, and the erroneous presentation of atomic weights, e.g., Uranium (116) and Erbium (56). The latter was incorrect because Mendeleev used a wrong valency which he then substituted in the equation: *atomic weight = combining weight x valency.* These inconsistencies display a tentative validity of the Periodic Law, and may imply doubts in terms of its utility and authority. Hence, Mendeleev could have resorted to a few attempts of modifying the Periodic Table to accommodate these inconsistencies and to correct his errors. This further suggests that the Periodic Law is not a fixed reference alone in arranging the elements based on a given data. On the other hand, Brush (1996) asserted that the Periodic Law gained a wide recognition and reception by the academe, particularly by textbook authors of chemical education as reported in his survey of academic texts. These textbooks published from 1870 to 1890 indicated that the Periodic Law was crucial in Chemistry pedagogy in America, Britain, and France. Thus, this shows that the acceptance of the academic community is reasonable enough to claim that the Periodic Law is instrumental in Chemistry education in those years. However, Brush (1996) admitted that only a fraction of chemists had mentioned the Periodic Law in their publications. In addition, it is also questionable whether a wide reception could be a sufficient and valid measure of a certain law's usefulness in science particularly in its applicability as a universal law.

Furthermore, by the year 1875, gallium was discovered based on the predictions made by Mendeleev. This remarkable event had aroused interest within chemical societies and made a solid confidence on the use of the Periodic Law for the succeeding determination of yet undiscovered elements (Brush, 1996; Soler, Zwart, Lynch, & Israel-Jost, 2014). By 1879 and 1886, two more elements were discovered, still using the Periodic Law as the basis, namely scandium and germanium. With such high accuracy of predictions just by using the Periodic Law, Mendeleev gained unrivalled recognition which was coupled with the entrenchment of his methods of predictions (Barnes, 2005). Having such recognition, Meyer's contribution on periodicity could have been displaced even though it portrays empirical methods in stark contrast to predictions by Mendeleev.

By analysis of the Periodic Law's nature, prediction remains the main driving force for the periodicity of elements. Hence, the arrangement of elements based on atomic weights during Mendeleev's dawning of Periodic Table construction paved way for chemists to draw conclusions on the possible location of an unknown element. But what does prediction play in the nature of science? Does it only apply to the periodicity of elements or is it a prevailing approach in science, the so-called 'novel prediction' as coined by some science philosophers? Are novel predictions in science and scientific law compatible in terms of the merits of the nature of science as referenced to the conception of scientific theories?

Predictivism in Science

The concept of prediction in science refers to the successful confirmation of a phenomenon even when an observation is absent

(Hitchcock & Sober, 2004). It is contrasted to accommodation in which the observations will obviously fit in to a certain theory because the observer had performed careful observations first before establishing that theory. Hitchcock and Sober (2004) claimed that predictivism is more acceptable than accommodation because novel predictions would make better confirmations without applying any bias of accommodating the facts that will fit into the theory or law. For example, Mendeleev's novel predictions of the three elements in the 1870's demonstrate a strong support to predictivism. Even so, the notion that predictivism is a valid approach in science is still questionable. In fact, one could reliably ask what could be the valid characteristics of predictivism that would qualify it as a functional scientific instrument.

Hitchcock and Sober stated the superiority of prediction,

> … a theory that predicts phenomena that were not used in the construction of that theory is, in some circumstances, better than a theory that accommodates the same phenomena. (p. 5)

If this is applied to the Periodic Law, there is an ample support that Mendeleev's table is superior over Meyer's graphical form. However, it must be noted that Meyer's representation involves an apparent empirical method, though it lacks the ability to predict the position of some elements due to the impossibility of having holes in the graph. So then, why was Meyer's work given less importance compared to Mendeleev's even though both were given equal recognition in their publication on periodicity?

To address this case, Brush (2007) maintained that predictions could play an important role in the establishment of a theory but not necessarily be a critical reference within scientific communities. As exclaimed by Scerri and Worrall (2001), "we find little support for the standard story that these predictive successes were outstandingly important in the success of Mendeleev's scheme" (p. 407). It is then argued that accommodation was likely utilized in the arrangement of the elements during that time because the chemical data must match with their relations concerning similarities in the properties of elements. With this, prediction could have been used by Mendeleev and his adherents in order to support the periodicity of both the existing and unknown elements in their time without any scientific methodology or argument pertaining to the use of Periodic Law. Thus, how successful predictivism was in determining the yet unknown elements in the 1870's onwards is still a critical scientific question to be pondered in the realm of scientific philosophical discourse.

DERIVATION OF A SCIENTIFIC LAW

A law, i.e., scientific law, is "a descriptive generalization about how some aspect of the natural world behave under stated circumstances" (National Academy of Science (NAS), 1998, p.5 as cited in McComas, 2003). This definition implies that a scientific law must be universally accepted and provides us a knowledge of the phenomenon or process. According to Dilworth (1989), a scientific law, e.g., empirical laws, is *discovered or developed* but not created, which is the case of a theory. Theory on the other hand is "*speculative and hypothetical in nature*" (p. 9); and that if later it is proven correct, may turn into a law unless otherwise substantially refuted through empirical proofs (e.g., geocentric model). In exact sciences such as physics and chemistry, scientific laws can be termed empirical laws (Dilworth, 1989). Dilworth asserted that these empirical laws require mathematical expressions that relate various parameters or variables which are subject for testing, i.e., through accurate measurements. Thus, in order for a scientific law to operate, it must not only predict the phenomena or process but it must also provide a concrete empirical method that demonstrates a clear scientific procedure or calculation in order to explain a universal truth. However, characterizing a scientific law simply as a mathematical expression in explaining physical phenomena has raised tensions among scientists. Nowak (1972) criticized Nagel's *The Structure of Science* by asserting that certain scientific laws have limits. Therefore, they are only an approximation under certain ideal conditions. For example, the Clapeyron equation, a typical gas law, only operates for perfect gases but is not appropriately suited for real gases. Thus, if this equation does not hold true as a mathematical expression in certain conditions, its universality is particularly questionable.

Moreover, Mitchell (2000) contended that philosophers failed to consider biological laws as scientific laws just because most biological generalizations are expressed in abstract linguistic forms. This led Mitchell to reflect:

> …we need to think of scientific laws in a very different way: to recognize a multidimensional framework in which a knowledge claims maybe located and to use this more complex framework to explore the variety of epistemic practices that constitute science (p. 243).

These contrasting views about the validity of a scientific law, then, constitute a wider dimension; and this requires an unbiased perspective in qualifying a scientific law to be universally accepted and true.

PERIODIC LAW VERSUS SCIENTIFIC LAW

Even though Mendeleev was able to predict, with almost exact precision, the properties of gallium, scandium, and germanium as a product of utilizing the Periodic Law, skepticism about its nature as a scientific law was highly criticized. The Periodic Law was regarded as a special case because its nature is descriptive. According to Restrepo and Pachon (2006), Mendeleev "opened the way to cross the hypothetical border between inferential and descriptive science" (p. 190) by successfully predicting the properties of gallium, scandium, and germanium. This implies that though this law does not constitute an equation or a mathematical expression which are primary characteristics of the laws in physics, it can be utilized as an effective tool within the aspects of general trends among chemical elements.

In contrast, Soler, Zwart, Lynch, & Israel-Jost (2014) claimed that the Periodic Law failed to meet philosophical standards of a scientific law. Essentially, laws originate in the form of mathematical forms (Ruby, 1986). Since the Periodic Law is not expressed in a typical equation, philosophers of science claim that it does not qualify as a scientific law (see Scerri & Worrall, 2001; Worrall, 2005; Brush, 2007). This leads us to think whether a social coordination emerged within the scientific communities where Mendeleev belonged in order to entrench the Periodic Law, i.e., the Periodic Table, as a massive contribution to Chemistry. Such coordination was justified by Woody (cited in Soler, Zwart, Lynch, & Israel-Jost, 2014) and went further to critique that the predictive nature, if it really functions this way, of the Periodic Law is highly speculative and does not meet the standards of empirical methods. Moreover, if Mendeleev was able to establish a method of prediction using this law, and was successful in its usage, then why would other scientists not resort to this approach?

Philosophers of science argue that the predictive nature of the Periodic Law influences its dubious function as a scientific law (Soler, Zwart, Lynch, & Israel-Jost, 2014). Woody (cited in Soler, Zwart, Lynch, & Israel-Jost, 2014) commented that the Periodic Law

> …is never explicitly cast as a logical conditional and only seldom, in the earliest years of its development, were efforts made to generate a precise mathematical expression; indeed, most of the time the law is not rendered in words at all… Even so, philosophical literature often seems implicitly to accept the periodic law as a genuine law. Discussions of accommodation versus prediction, for example, appear to assimilate it to **traditional conceptions of law**, for which the notion of prediction is generally well defined. (p. 4).

In addition, it should be noted that both Mendeleev and Meyer were awarded the Davy medal for their contribution on periodicity. However, Akeroyd (2003) asserted that Mendeleev seem to receive only the wider recognition of being the sole author whereas Meyer's graphical presentation received lesser reception. Akeroyd contended that Spottiswoode (1883, cited in Akeroyd, 2003) did not even give premium citation to the successful predictions of Mendeleev which implies that its intended usefulness was not of critical importance at the time within the scientific communities. But how this merit to Mendeleev's law ended up being entrenched among social circles is still criticized. Mendeleev's critical response 'that Meyer did not comprehend the deeper meaning of the periodic system' (Akeroyd, 2003, p. 341) constitute a bitter rivalry that would attract a wider acceptance of Mendeleev's proposition. In contrast, if Mendeleev was the sole recipient of the Davy medal, predictivism could have gained the best approach in the establishment of the periodic system. As Meyer's legacy fades away from the conception of the Periodic Law, it is apparent that there is likely an exclusive bias in representing periodicity which, in this case, favors the predictions of Mendeleev.

Moreover, Brush (2007) asserted that the use of accommodation in the success of the Periodic Law does not necessarily mean that it is an alternative to prediction. In fact, Brush contended, few of the facts or data were coerced in order to fit in the requirements of the law, e.g., the accommodation of the atomic weights of beryllium and tellurium. This implies that the Periodic Law may have claimed its success from predictivism; however, this is not a rigid basis for the periodicity, if this term even applies, considering that even scientists do not agree whether predictivism is an acceptable approach just as the general notion that there is no specific scientific method for any inquiry.

Periodic Law and its Implications to the Nature of Science (NOS)

One aspect of the nature of science involves understanding the conceptual frameworks and processes in science. McComas (2003) asserted that a critical factor in understanding the nature of science lies on examining the processes involved in the formulation of a scientific law. As pointed out by Soler, Zwart, Lynch, & Israel-Jost (2014), Scerri and Worrall (2001) and Brush (2007), the Periodic Law lacks a few characteristics of a scientific law. The prevailing criticism to this law is its predictive nature. At that time, Mendeleev was a flourishing chemist due to the discovery of the three elements mentioned. The physicochemical properties of these newly discovered elements matched those that were predicted by Mendeleev, and so this had probably entrenched the law's validity and acceptance among some scientists within the scientific community at that time.

However, in the formative years of the Periodic Law used in establishing the Periodic Table, many errors have been seen even in the papers published by Mendeleev starting 1869. For example, Mendeleev placed gold in Group IIIA, lead in Group IIA, and thallium in Group IA (Obshchestva, 2014). In addition, the atomic weights of indium, thorium, and uranium were all incorrect resulting into their imprecise placement in the Periodic Table. Due to this, Mendeleev has to correct their atomic weights, and hence their position in the Periodic Table would also change. Such re-arrangement leads to the tentativeness of the use of the Periodic Law when predicting the location of the unknown elements. This was remarkably indicated in Mendeleev's 1872 paper in response to his critics. Thus, the tentativeness of Mendeleev's Periodic Law is clearly seen in his further modification of the Periodic Table based on the comments of his fellows. This indicates that the use of the Periodic Law is likely to be tentative even in its final form and chemists could not generally deduce that this law defines the entirety of the arrangement of the elements in the modern Periodic Table.

Moreover, since both Mendeleev and Meyer offered their own representational format of the Periodic Law, it is not conclusive which one genuinely reflects the arrangement of the elements. As argued by Soler, Zwart, Lynch, & Israel-Jost (2014),

> Indeed, perhaps the most intriguing issue here is that while both representations were legitimate contenders, and were treated as such by practitioners, one could hardly deny that what these artifacts represented was not equivalent (nor even straightforwardly inter-translatable) … At the time of its introduction, the content of the Periodic Law was neither obvious not settled. (p. 8)

Hence, the assumption that Mendeleev's version of the Periodic Law is more superior than Meyer's graphical form is highly inconclusive. Accordingly, based on Mendeleev's (1871, as cited in Soler, Zwart, Lynch, & Israel-Jost, 2014, p. 8) assertion: "I define the law of periodicity as the mutual relations between the properties of the elements and their atomic weights which can be applied to all the elements. These relations have the form of a periodic function", obviously the mistakes he committed in his first few papers contradict the law itself. In addition, Obshchestva (2014) mentioned that Mendeleev, in his paper published in *Zhurnal* in 1869, presented the periodicity in a logical form. The use of logic would mean that its interpretations may vary, and as a result, its universality as a law is nullified. The predictive nature of the Periodic Law was likely denounced by Lothar Meyer who worked in a similar context and goal as Mendeleev but with a different approach. According to Scerri (2020), the German academic institutions at the time, where Meyer is a practicing chemist, have a high disregard to speculations. This might be the reason why Meyer's graphical presentations of his evidence of periodicity gave no further hints of predictions to undiscovered elements.

The question, then, is if the Periodic Law becomes valid only through successful predictions, does the nature of science affirm prediction as an acceptable process in scientific investigations? In a critical discourse, Scerri and Worrall (2001) write,

> No one could deny, of course, that it is one thing for a theory to make predictions of the existence of the hitherto unknown elements and quite another for it to make *successful*, empirically verified predictions (p. 413).

In fact, Mendeleev, by using the predictive power of the Periodic Law, was unsuccessful in his attempt to predict the succeeding elements after germanium (Scerri & Worrall, 2001). These failed attempts suggest that mere speculations or predictions may disqualify the

Periodic Law in the realm of scientific laws (Soler, Zwart, Lynch, & Israel-Jost, 2014; Brush, 2007).

Further, Erduran (2007) stated that

> Predictions that are made from the so-called Periodic Law do not follow deductively from a theory in the same way in which idealized predictions flow almost inevitably from physical laws, together with the assumption of certain initial conditions (p. 255).

Consequently, the Periodic Law *does not* necessarily predict the existence of the unknown or undiscovered elements; those elements were already existing, and their discovery was the result of an empirical investigation carried out by their discoverers. Their properties, then, were just affirmed by the data that Mendeleev has previously laid out. Thus, this leads us back to ponder whether the Periodic Law by Mendeleev acquires the attributes of the nature of science as finding for the ultimate processes that can justify the products of science, e.g., the discovery of elements.

CONCLUSION

The Periodic Law has been regarded as one of the greatest tools in establishing the chemical theory by its predictive nature. Such descriptive nature has been highly criticized by the scientific community as well as science philosophers because it does not possess some of the qualities of a scientific law. In contrast, it has been widely debated whether abstract linguistic forms in the sciences, such as those that are not expressed in mathematical equations, could qualify as a scientific law. In effect, this might likely put the Periodic Law at the risk of being displaced as a scientific law. Based upon the mistakes committed by Mendeleev in his early attempts to arrange the elements, it is now clear that the tentativeness of the Periodic Law would mean that it might not be generally accepted as the only instrument that could be used in arranging the elements in the modern Periodic Table nor in predicting the yet undiscovered elements. In the case of the Periodic Law, philosophers indicated that its acceptance by the scientific community at the time after the subsequent discoveries of gallium, scandium, and germanium was likely a psychological impact of the high accuracy of its predictions. Thus, the institutional forms at the time had a high confidence in Mendeleev's method, and regarded the Periodic Law as an essential law that can guide into their discovery of yet undiscovered elements. However, it was seen that the work of Meyer, characterized with more empirical evidence, displayed a stark contrast to the predictive nature of the Periodic Law. Meyer's work indicates a displacement of speculative processes in science that demands more scientific evidence to support its claims.

As a result of its increasing criticism in the realm of scientific laws, Scerri and Worrall (2001) questioned and pondered about the Periodic Law

> …, then if the success of the predictions it made was going to prove the crucial evidence that greatly increased its rational believability and gave the scientific community a high confidence in further predictions from it, what would be the expected attitude amongst that community towards the scheme in 1869/71? Surely it would be one not of scepticism but rather of everything…is going to depend on whether or not these bold *predictions are verified* (with emphasis) (p. 414).

As argued, if the Periodic Law lacks merits of a scientific law, then it may likely violate the nature of science. The processes involved in the successful prediction of some elements need to be verified. In addition, explanations as to why the succeeding predictions after germanium that constituted many failed attempts are required. Deeper reflections and argumentation on the genuine functionality of the Periodic Law to justify the products of science, e.g., discovery of elements, entails further scientific discourse.

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