EARLY RESPONSES to the PERIODIC SYSTEM

Edited by

Masanori Kaji · Helge Kragh
Gábor Palló

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FOREWORD

Although a great number of historians have studied Mendeleev's discovery of the periodic system of chemical elements, few have looked at how the scientific community has perceived and employed this system in various areas of the world. This book fills this gap. In addition, for the evaluation of the periodic system, this book looks not only at scientific communities, but also at the educational sector and local popular culture.

The idea of a comparative project on the early reception of the periodic system occurred to one of the editors (Masanori Kaji) during the 6th Science and Technology in the European Periphery (STEP) meeting in Istanbul in June, 2008.

He engaged historians of chemistry and organized sessions devoted to this project at international conferences: the 7th International Conference on the History of Chemistry (Sopron, Hungary, August 2–5, 2009); the 7th STEP meeting (Galway, Ireland, June 17–20, 2010); and the 4th International Conference of the European Society for the History of Science (Barcelona, Spain, November 18–20, 2010). After these meetings, the following fifteen participants were brought together for this project, accounting for eleven countries and one region:

Gisela Boeck (Germany), Nathan Brooks (Russia), Marco Ciardi (Italy), Antonio García Belmar (France), Masanori Kaji (Russia and Japan), Helge Kragh (Denmark), Anders Lundgren (Sweden), Annette Lykknes (Norway), Isabel Malaquias (Portugal), Rosa Muñoz Bello (Spain), José Ramón Bertomeu Sánchez (Spain), Soňa Štrbáňová (the Czech Lands), Marco Taddia (Italy), Bernadette Bensaude-Vincent (France), and Gordon Woods (Great Britain).

These individuals all agreed to contribute papers to a collective work, and Masanori Kaji, Helge Kragh, and Gábor Palló agreed to serve as the editors. This book is important, not only for the obvious audience of historians of chemistry, but also for the larger community of historians of science and ideas and for the much larger community of chemists. Moreover, it contributes significantly to the history of pedagogy and popularization in science. It reexamines various concepts in reception studies other than "reception," such as "response" and "appropriation." It also offers new arguments in the philosophical debate of the impact of scientific discoveries.

Masanori Kaji
Helge Kragh
Gábor Palló

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Early Responses to the Periodic System

CHAPTER 1

Introduction

MASANORI KAJI, HELGE KRAGH,
AND GÁBOR PALLÓ

Even though there have already been many studies of the reception of scientific discoveries and theories, only a few discoveries have been systematically examined from a comparative perspective, in particular Darwin's theory of evolution in biology and Einstein's relativity theory in physics.[1] In the field of chemistry, the periodic system of the elements is a good candidate for such comparative reception studies. Although the discovery of the periodic system and its later history have generated numerous inquiries,[2] its reception has received only partial or scanty attention. In his noted paper published in 1996, the American historian of science Stephen G. Brush explored the role that successful predictions and accommodation of known facts played in persuading scientists to accept scientific discoveries.[3] He systematically examined textbooks and comprehensive chemistry reference works, observing that, "[the] number of explicit references to the periodic law to be found in late nineteenth-century chemistry journals is small and fluctuates irregularly."[4] Relying on a survey of textbooks and reference works written between 1871 and 1890 and existing in American libraries, he concluded that the periodic law had been generally accepted in the United States and Britain by 1890.[5] In a footnote to the same paper, he suggested the need to extend this study of texts to other countries, especially Germany and France.[6]

In fact, two years before Brush's paper was published, Ludmilla Nekoval-Chikhaoui had completed her dissertation on the diffusion of Mendeleev's periodic classification in France.[7] She studied this subject as part of a project on the diffusion of scientific knowledge from the second half of the nineteenth century to the early twentieth century. Basing her examination on scientific journals and chemistry books, Nekoval-Chikhaoui analyzed the diffusion of the periodic system in the French scientific community.[8] She also surveyed the introduction of periodic classification in higher and secondary education based on an analysis of chemistry textbooks, higher education courses, and public education programs. At the end of her dissertation, she called to conduct a comparative analysis of the diffusion of Mendeleev's discovery in different European countries.[9] However, Nekoval-Chikhaoui's call and Brush's suggestion went unmet; no comparative studies on the reception of the periodic system followed. Therefore, this book constitutes the first major step toward a response.

When we started our comparative work, we listed the following topics for study:

What were the first or earliest journal papers, chemistry textbooks, or reference books that mentioned the periodic law in the country examined? Were they written by local authors or translated from other languages? Who were these authors? Wherever possible, we provide quantitative data concerning the number of textbooks for the period between 1870 and 1920 in which the periodic law was mentioned.

How did local actors perceive the periodic law? Did they regard the new discovery as a law, as a classification, or as a theoretical interpretation? How did this treatment and perception change over time?

Why was the new classification appropriated and employed? Was it used for teaching or research? What happened to the old chemical classifications? Were they abandoned after the introduction of the periodic classification? Did some authors criticize or reject the new classification? If so, why?

Were there any arguments about the implications of the periodic law for the structure of matter? Was the periodic law related to controversies concerning atomic theory? Was it associated with other ideas about the nature of matter, such as elements vs. elementary substances, or more general theories of the universe, such as evolutionism and cosmology?

For the periodic law in the public sphere, was the discovery reported in popular books, lectures, and periodicals? In which journals and for what audience was the discovery reported? Who were the journalists interested in the subject? What was the perception of the discovery and its consequences in the popular media? Did this change during the period under study?

Were the papers on the periodic law translated into the local languages? From which papers were they translated? In which journals/publications did they appear? Who was their intended audience? Who were the translators?

Who was the discoverer of the periodic law/system according to the local actors? Did priority controversies take place?

What was the impact of new discoveries like those of gallium, scandium, germanium, the rare earths, and noble gases or the discovery of radioactivity on the perception of the periodic law? Did they have any influence on the contents of textbooks and reference books? What were the consequences of the periodic law as perceived by the historical actors?

Were there any further research studies to develop the periodic law by local researchers? New classifications? New interpretations? New predictions?

The fifteen authors in this book survey all or some of the questions mentioned previously as they apply to ten countries and one region in Europe, as well as Japan. They describe the various circumstances concerning responses to the periodic system in these locations. The study covers the period spanning the 1870s to the 1920s, before the advent of quantum mechanics. In a few cases, the authors refer to earlier periods for reasons of comparison and to later periods for analysis of secondary education textbooks. Some authors have examined journal articles, reference books, and chemistry textbooks for both higher and secondary education, while others have reviewed popular books and magazines and educational curricula or examinations prepared by local or national governments.

We are aware that the categories of *reception* and *diffusion* have been criticized in recent years for their static conception of scientific theories, which are then *transferred* to passive recipients. Critics have proposed other terms, such as "response" or "appropriation."[10] We allowed the individual authors to decide which term would be appropriate for their paper.

AN OVERVIEW OF THE BOOK

Part I deals with the two countries from which the periodic system originated, namely, Russia and Germany. Chapter 2 on Russia (by Masanori Kaji and Nathan Brooks) discusses Dmitrii Ivanovich Mendeleev's compilation of the first table of elements. By the autumn of 1870, Mendeleev had completed a refined version of the periodic system, with detailed predictions of undiscovered elements in Russian, which was translated into German and published in the German journal "Annalen der Chemie und Pharmacie" the following year. The Russian response to the periodic system was different from that elsewhere because of Mendeleev's presence. As the main figure of the new Russian Chemical Society, founded in 1868, he succeeded in persuading the leading chemists in his home country of the validity of the periodic law. German-speaking chemists in the Russian Empire (our authors call this "German mediation") and Mendeleev's famous chemistry textbook *Osnovy khimii* (*The Principles of Chemistry*) played an important role in disseminating the periodic system both inside and outside Russia. Since Russia did not have a strong educational tradition, as France and Spain had, a new approach based on the periodic system was smoothly implemented in Russian secondary education in the 1880s.

Chapter 3 on Germany (by Gisela Boeck) features Lothar Meyer, another discoverer of the periodic system, as recognized by the Royal Society of London, which awarded the Davy Medal in 1882 to Meyer and Mendeleev jointly. However, in contrast to Mendeleev's case, Meyer's role in the discovery was considered less important, even by his colleagues, and became more or less forgotten in his home country. The periodic system was used only on a limited scale in research in Germany. The German educational tradition was well established, and the periodic system was not used as a novel didactic approach. Instead, popular journals mentioned the periodic system in connection with the origin of the elements, the evolution of inorganic matter, or the theory of descent of biological species.

Part II deals with two countries taking center stage in chemical research: Great Britain and France. Chapter 4 on Great Britain (by Gordon Woods) starts with preliminary research on the terms *periodic system, periodic law, periodic classification*, and *periodic table*. After a brief explanation of British contributions to the periodic system, such as those of J. A. R. Newlands, W. Odling, W. Ramsay, J. J. Thomson, F. Soddy, and H. Moseley, along with an examination of academic books, the author concludes (as Brush did in the case of the United States) that by the late 1880s, the periodic law had been generally accepted by academic chemists. He also broadly analyzes educational scenarios in Britain, using not only textbooks for universities and schools but also curricula, syllabi, and examinations, which reveals that the periodic system was not a central theme of inorganic chemistry until approximately 1920.

Chapter 5 on France (by Bernadette Bensaude-Vincent and Antonio García Belmar) reveals a conspicuous silence regarding the periodic system or classification. A small but significant group of authors adopted Mendeleev's views, including Adolphe Wurtz and Édouard Grimaux. However, they introduced the periodic system not as the final solution to the long-standing quest for a natural classification of elements, but as support for the atomic theory. Their argument was that the system depended crucially on atomic weights and could not be deduced from equivalents. In France, the traditional and unsolved problem of classification in chemistry led educators to consider classificatory issues to be a subject reserved for advanced students.

Part III includes Chapter 6 (by Soňa Štrbáňová), dealing with the central European periphery, that is, the Czech Lands. The Czech chemist Bohuslav Brauner played a crucial role in the reception of the periodic system. He initiated chemical research when European chemists started to pay attention to Mendeleev's system with the discovery of gallium in 1875. From that point, Brauner became an enthusiastic promoter of the periodic system and endeavored to perfect it, especially with regard to the position of the rare earths in the periodic table. The time span of the chapter covers the period when Czech-German antagonism reached Czech scientific institutions. The Society of Czech Chemists, founded in 1866, had an almost exclusively Czech membership, while a specialized German chemical association had never been created in the Czech Lands. Universities split into their Czech and German counterparts. Even though Brauner himself had a cosmopolitan background, Mendeleev and his works, including the periodic system, were celebrated as a brilliant representation of Slavic science.

Part IV deals with the northern European periphery, including the three Scandinavian countries of Sweden, Denmark, and Norway. The chapters in this part describe indifference to the periodic system, much as in France, but for different reasons. Chapter 7 (by Anders Lundgren) explains that a long-standing practical and atheoretical tradition of Swedish chemistry was unaffected by the periodic system, with many new elements discovered by Swedish chemists independently of the system. Because Swedish chemists at the time had little interest in theory, they did not require any explanation of the periodicity of the elements. Nor was the periodic system used as a pedagogical tool for textbooks. Lundgren contends that Mendeleev's periodic system might not have been as important as historians of chemistry have traditionally believed.

Chapter 8 (by Helge Kragh) notes that when the Danish Chemical Society was founded in 1879, the first of its kind in Scandinavia, there were only two full professors and three associate professors in Denmark, and most of the country's chemists had a practical orientation. Kragh argues that although the first published recognition of the periodic system by a Danish chemist dates back to 1880, many chemists were aware of the classification even earlier. The first chemistry university textbook, which included a detailed account of the periodic system, was published in 1902, but the system did not function as an organizing principle of the text. In the early twentieth century, only a few textbooks for secondary education referred to or used the periodic system. Julius Thomsen, a pioneer of thermochemistry, was the only Danish scientist who actively sought to understand the periodic system. Kragh further argues that some of Thomsen's ideas inspired Niels Bohr's development of his atomic theory in 1913.

Chapter 9 (by Annette Lykknes) discusses the condition of chemistry in Norway, which resembled that of other Scandinavian countries. The Norwegian chemistry community was very small: only one professor in chemistry until 1872, three chairpersons in Christiania and four in Trondheim in the 1930s. Most chemists were employed in industry and had a very practical orientation. The periodic system was first mentioned in a chemistry textbook published in 1888, not in a scientific journal. Norwegian chemists started citing the periodic system in research journals in the 1910s, when problems of radioactivity and atomic theory renewed chemists' interest in the system. However, the periodic system was introduced as a pedagogical tool in the universities only in the 1940s. Remarkably, the inclusion of the periodic system in Norwegian textbooks used in gymnasia (the equivalent of high schools) did not begin until 1970 because of the monopoly of one chemistry textbook, which happened to deny the usefulness of the periodic system.

Part V deals with countries of the southern European periphery, namely, Spain, Portugal, and Italy. Chapter 10 (by José Ramón Bertomeu-Sánchez and Rosa Muñoz-Bello) explains the limited role of the periodic system in the teaching of chemistry in Spain between 1870 and 1920 by the existing tradition of chemistry textbooks. As in France, there were long-standing debates on the classification of chemical elements and compounds into *artificial, natural*, and *hybrid* classifications. Consequently, Spanish textbook authors were not that impressed by the possible classification offered by the periodic system. After the first successful prediction of new elements and the publication of Mendeleev's paper in French journals, the periodic table was disseminated in Spanish textbooks. However, the textbook authors did not consider the system to be the basis of classification of the elements, only as a way of introducing theoretical topics, such as the existence of atoms, Prout's hypothesis, the evolution of inorganic matter, and even the origin of the universe.

Chapter 11 (by Isabel Malaquias) explores traces of Mendeleev's periodic system in Portuguese higher education and secondary textbooks, some popular books, and several booklets published at the end of the nineteenth and early twentieth centuries. Although periodic classification was adopted officially as a topic to be taught in Portuguese secondary education only in 1948, some professors had already made reference to the system early in the twentieth century. Malaquias has found a letter by Mendeleev, dated February 4, 1904, to Balthazar Ozorio, a zoology professor at the Lisbon Polytechnic School, where Mendeleev mentioned Ozorio's discovery of possible impurities of iodine.

Chapter 12 (by Marco Ciardi and Marco Taddia) is the first attempt to study the reception of the periodic system in Italy. In 1879 an Italian translation of Wurtz's *La Théorie Atomique* was published, which explained Mendeleev's periodic system in detail. In Florence, Augusto Piccini, an assistant of Stanislao Cannizzaro, played an important role in promulgating Mendeleev's system and received a letter from Mendeleev, dated January 29, 1903. Giacomo Ciamician, another of Cannizzaro's assistants and a chemistry professor in Bologna, also taught general chemistry based on the periodic system from at least the end of the nineteenth century and contributed to work on the system in Italy. The authors have examined university chemistry textbooks and a well-known secondary education textbook by Fausto Sestini and Angelo Funaro in the nineteenth century.

Part VI includes Chapter 13 (by Masanori Kaji) about Japan, one of the few countries outside the Western world that participated in modern scientific research in the nineteenth century. The discovery of the periodic law in 1869–1871 and its dissemination in the 1880s coincided with the institutionalization of chemistry in Japan after the Meiji Restoration in 1868. This factor helped facilitate the appreciation of the periodic system as a basis for chemistry there. Most of the first-generation Japanese chemistry professors accepted without much skepticism the periodic law as one of the recent developments in chemistry in Europe. Furthermore, around this time, Japanese chemists began to contribute to the study of the periodic system. For instance, Ogawa Masataka announced the discovery of a new element called nipponium in 1908, which much later turned out to be rhenium.

The papers in this book thus shed light on a multitude of responses to the periodic system. The smallness of the chemical community, for example, played a role in the Scandinavian countries' reaction to the system. Consequently, even among chemists who had a practical orientation and who did not pay much attention to theory in general, one particular researcher with an interest in theory—such as Julius Thomsen, a pioneer of thermochemistry in Denmark—could change the situation. Thomsen offered a neo-Proutean speculation of internally structured atoms, which Mendeleev denied, but his ideas inspired Niels Bohr's development of an atomic theory in 1913. In Norway, by contrast, one chemistry textbook that happened to deny the periodic system and that was dominant in secondary education, delayed the system's reception there until as late as 1970.

In Sweden, where chemistry remained an atheoretical science, the periodic system did not bring about any change in education or research. The periodic system also did not impress chemists in France and Spain, where there was a long tradition of and debate about the classification of matter. Some research considered the system to be the worst kind of natural classification, which did not show chemical analogies clearly. Before the advent of atomic structural theories and quantum chemistry, the periodic law faced the difficulty of breaking with the tradition, and German teachers within the established practice of chemistry education did not find any novelty in it as a didactic tool.

On the other hand, in countries such as Russia and Japan, where there was no strong tradition in education, the periodic system was readily accepted. In places where there were devoted researchers, such as Mendeleev himself or Bohuslav Brauner, his influential coworker, the acceptance of the periodic system was a momentous event, as in the case of Russia or the Czech Lands. The coincidence of the institutionalization of science, including chemistry, and the discovery of the periodic law, helped Japanese chemists to accept the law without much problem.

These comparative studies reveal the relative insignificance of the periodic system in research and teaching in many countries, which is contrary to the understanding of most historians of chemistry. Of even greater interest is the fact that in the late nineteenth and early twentieth centuries, many metaphysical and philosophical reflections on nature based on the periodic system appeared outside of chemistry. Even in Russia, where there was an exceptional impact on both research chemists and chemical education, some intellectuals were trying to speculate about the reasons for the periodic law at the end of the nineteenth and early twentieth centuries. In Germany, where the periodic system was used only on a limited scale in research and was not employed as didactically, the popular journals mentioned the system in connection with the origin of the elements, the evolution of inorganic matter, or the theory of descent. In Spain, Mendeleev's system offered good opportunities for popularizers of science to speculate on various theoretical topics, such as the existence of atoms, Prout's hypothesis, the evolution of inorganic matter, and the origins of the universe. However, neither the practice nor the strategy changed in research and teaching of chemistry because of the periodic system, probably because chemists were practice oriented, as was clearly the case in the Scandinavian countries.

It may be wondered why the papers in this book are categorized by nation-states.[11] Besides aiding with the manageability of the research, the time span coincides with the age of the nation-states, so taking the nation-state as a unit of study makes sense historically. At the same time, this framework can highlight some features that lie outside its scope, including the German-speaking scientists working outside Germany, such as in Russia and the Czech Lands. In the former Russian Empire, German nationals and subjects of the empire played an important role in promulgating the periodic system beyond the Russian border. The chapter on the Czech Lands poses a question about the expatriate German chemical community when Czech-German antagonism reached the Czech scientific institutions and universities split into their Czech and German counterparts. In addition, French influence played a certain role in the southern European periphery, and in Japan, British chemists, who were employed as teachers in higher education soon after the Meiji Restoration in 1868, played a positive role in the early introduction of the periodic system there.

Our collective work has several limitations that suggest the direction of further studies. The first is the obvious restriction in terms of countries and regions, neglecting other potentially interesting cases, such as Ireland, Canada, Mexico, Brazil, Argentina, China, India, and Australia.

A second limitation pertains to the time frame. The scope of our reviews more or less ends in 1920, before the advent of quantum chemistry. For this later phase, where a quite different response to the periodic system may be seen, we need another book like this one.

A third limitation relates to the lack of graphic representations of the periodic system. None of our papers discusses this component, even though some topics, such as Thomsen's periodic system in Kragh's chapter, imply its significance. We are well aware that a large number of graphic representations were created, with their own histories and visual accounts closely connected to chemistry.[12]

Notwithstanding our awareness of these and other limitations, we hope that this collective work of historians of chemistry might provide inspiration for new scholarly research on the reception of the periodic system.

NOTES

1. See *The Comparative Reception of Darwinism*, ed. Thomas F. Glick (Chicago and London: The University of Chicago Press, first published in 1974, reissued in 1988 with a new preface, "Reception Studies Since 1974"); *The Comparative Reception of Relativity*, ed. Thomas F. Glick (Dordrecht, Boston, Lancaster, and Tokyo: D. Reidel Publishing Company, 1987); *Disseminating Darwinism: The Role of Place, Race, Religion, and Gender*, ed. Ronald L. Numbers and John Stenhouse (New York: Cambridge University Press, 1999); *The Reception of Darwinism in the Iberian World: Spain, Spanish America and Brazil*, ed. Thomas F. Glick, Miguel Angel Puig-Samper, and Rosaura Ruiz (Dordrecht, Boston, and London: Kluwer Academic Publishers, 2001).
2. See, for example, J. W. van Spronsen, *The Periodic System of Chemical Elements: A History of the First Hundred Years* (Amsterdam: Elsevier, 1969); Eric Scerri, *The Periodic Table: Its Story and Its Significance* (Oxford, New York, etc.: Oxford University Press, 2007).
3. Stephen G. Brush, "The Reception of Mendeleev's Periodic Law in America and Britain," *Isis* 87 (1996): 595–628.
4. Brush (note 3), 600.
5. Ibid., 601.
6. Ibid., 601, n. 12.
7. Ludmilla Nekoval-Chikhaoui, "Diffusion de la classification périodique de Mendéléïev en France entre 1869 et 1934" (PhD Diss., Univ. Paris-Sud U.F.R. Scientifique d'Orsay, 1994).
8. Nekoval-Chikhaoui used "la classification périodique de Mendéléïev" [Mendeleev's periodic classification] more often than "la loi périodique" [the periodic law]. Brush (note 3) used the term "law."
9. Ibid., 140.
10. See, for example, Kostas Gavroglu, Manolis Patiniotis, Faidra Papanelopolou, Ana Simões, Ana Carneiro, Maia Paula Diogo, Joé Ramón Bertomeu Sánchez, Antonio García Belmar, and Agustí Nieto-Galan, "Science and Technology in the European Periphery: Some Historiographical Reflections," *History of Science* 46 (2008): 153–175.

11. For information on the limitations of comparative studies based on national boundaries, see James A. Secord, "Knowledge in Transit," *Isis* 95(4) (2004): 654–672, p. 669.
12. For graphical representations, see F. P. Venable, *The Development of the Periodic Law* (Easton, Pa.: Chemical Publishing Co., 1896); E. Mazurs, *The Graphic Representation of the Periodic System During 100 Years* (Tuscaloosa: University of Alabama Press, 1974).

PART I

Discovery and Early Work on the Periodic System

CHAPTER 2

The Early Response to Mendeleev's Periodic System in Russia

MASANORI KAJI AND NATHAN BROOKS

1. INTRODUCTION: DISCOVERY OF PERIODIC LAW OF CHEMICAL ELEMENTS BY MENDELEEV

Mendeleev's first table of elements, entitled "An Attempt at a System of the Elements Based on Their Atomic Weight and Chemical Analogies,"[1] was dated February 17, 1869.[2] His first paper on the discovery, "The Correlation of the Properties and Atomic Weights of the Elements"[3] (hereafter referred to as Paper I), was read in the meeting of the newly established Russian Chemical Society (RCS)[4] on March 6 by Nikolai Aleksandrovich Menshutkin (1842–1907), the secretary of the Society for Dmitrii Ivanovich Mendeleev (1834–1907), who was not able to attend the meeting since he was visiting various cheese-making factories outside the city.[5] The members of the Society who attended this meeting decided not to discuss Mendeleev's paper, and it was tabled until the next meeting. The paper was published in the second/third combined issue of the first volume of the Society's journal in May (Paper I).

Paper I was the first public announcement of one of the most important discoveries in nineteenth-century chemistry: what would soon be called Mendeleev's "periodic law." However, the paper did not draw immediate attention from the chemists at the meeting. While this muted response was similar to the initial reception of the periodic system in other countries,[6] the reception of the periodic system in Russia was distinctive for various reasons. This paper will examine some of these factors first.

The most obvious difference between the reception of the periodic system in Russia as compared to other countries is simply due to the fact that Mendeleev was Russian. Thus, the reception of the periodic system in Russia needs to be considered in the context of Mendeleev's place in the Russian chemical community, as well as in intellectual terms.

In 1869, at the time of Mendeleev's first announcement about the periodic system, the Russian chemical community was in the process of formation. During the first half of the century, the number of chemists with advanced training was small and nearly all of them were employed at higher educational institutions and the Imperial Academy of Sciences. In addition, these chemists exhibited a local orientation in which they concentrated their attentions on matters of concern for their local communities, not the larger community of chemists in Russia or in Western Europe. Some of these chemists did conduct research, but they did not establish sustained research schools or construct nationwide contacts among other chemists in Russia. This situation began to change with the death of Nicholas I (1796–1855, emperor of Russia 1825–55) in 1855 and the beginning of the Great Reform Era (1855–81) under Tsar Alexander II (1818–81, emperor of Russia 1855–81). Russians were again sent abroad at state expense to receive training in preparation for employment in higher educational institutions, something that had been prohibited during the years of 1848 and 1855. The employment opportunities for chemists and other educators also greatly expanded at this time, as the state increased the ranks of the professoriate in both the universities and the technical schools of higher education. The numbers of students studying at higher educational institutions also rapidly expanded at this time. By the late 1850s, there was a growing number of young chemists in St. Petersburg and elsewhere in Russia with advanced training, many of whom had studied abroad. These chemists began to plan the formation of a chemical society that would hold meetings to discuss their research and that would publish the results of this research, using as models la Société Chimique de Paris and the Chemical Society of London. For various reasons, this society was established only in 1868 in St. Petersburg, where a large number of higher educational institutions were located and where the majority of young chemists lived. Mendeleev was one of the organizers of this new society and he played an important role in its operation for many years.[7]

In 1869 Mendeleev was professor of chemistry at St. Petersburg University and had been there since 1865 when he first moved to the chair of technical chemistry.[8] Mendeleev had been a student at the Main Pedagogical Institute (Teacher's College), where many of the teaching staff also taught at St. Petersburg University. He graduated and worked as a secondary school teacher for less than a year before he returned to St. Petersburg to defend his master's dissertation. After working as a lecturer at various schools in the capital, Mendeleev was able to take advantage of study abroad, funded by the Ministry of Public Enlightenment. He then went to Heidelberg, where several other Russians were studying. Mendeleev was slightly older than many of his fellow Russian students, but managed to develop close friendships with other Russians. He did not spend much time in lectures, since he had solid theoretical training (this was the case for many Russian chemistry students who went abroad at this time and later). After spending most of his time in experimental work using equipment purchased in Europe, Mendeleev reluctantly returned to Russia, since he could not afford to stay abroad any longer. Following