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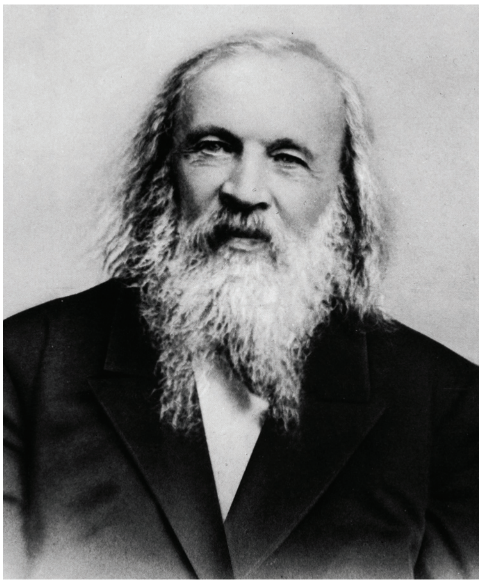

Dmitrii I. Mendeleev
(1834–1907)

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On February 8, 2009 it is 175 years since the birthday of Dmitrii Ivanovich Mendeleev, the author of the Periodic Law and Periodic System of Chemical Elements, with whose name our journal is connected.

The life of this versatile person was extremely rich in events, and his anniversary is a good occasion to remind some important points of Mendeleev's scientific biography.†

Dmitrii Ivanovich Mendeleev was born on February 8, 1834 in Tobolsk, Siberia, Russia. From the outset of his study Mendeleev showed his persistence, activity and deep knowledge of subjects he took an interest in. In 1849, Mendeleev graduated from the gymnasium at the age of 15, and in 1855, from the Principal Educational Institute in St.-Petersburg with golden medal for excellence. In 1856 at St. Petersburg Imperial University, he defended two magisterial theses: 'On Isomorphism and Specific Volumes' and 'On the Structure of Silica Compounds'.

After lecturing (theory and history of chemistry, and organic chemistry) as private docent of the university, in 1859 Mendeleev was sent to Europe, where he visited a number of universities, met with famous scientists, such as Berthelot, Würtz, Dumas, Liebig, Bunsen, Erlenmeyer and Kirchhoff, established a private laboratory at Heidelberg, took part in the First Chemistry Congress in Karlsruhe. During his work in Heidelberg, Mendeleev designed a number of devices (including his famous Mendeleev's picnometer) and discovered a phenomenon of absolute boiling point (now known as critical temperature).

Just after his return to St. Petersburg in 1861, he began to write a handbook 'Organic Chemistry', for which he was rewarded with the Demidov Prize of 1862. In 1861–1862 as the editor of the translation of Wagner's 'Technology', Mendeleev wrote for this book additional chapters on Starch, Sugar, Alcohol and Glass Industry. His study in the field of technology Mendeleev continued as a docent at the Technology Chair of the University and a professor at St. Petersburg Practical Technological Institute. At the same time, he engaged in fundamental problems of the physical chemistry of liquids and solutions and in 1865 he received his PhD from the University for his Doctoral thesis 'On the Compounds of Alcohol and Water' and the position of a professor on technical chemistry at the University.

Mendeleev made a very important contribution to the creation in October 1868 of the Russian Chemical Society, which ten years later was transformed to the Russian Physico-Chemical Society with two autonomous divisions – physical and chemical. He wrote the regulation for the Russian Chemical Society and served as the president of the Russian Physico-Chemical Society in 1883–1887. Since 1932, the national Chemical Society has the name of D. I. Mendeleev.

In 1868, Mendeleev received a new duty to teach students with the course of inorganic chemistry, the topic relatively new for himself. Surprised by the lack of suitable handbooks (to be recommended for students), he decided to write his own course. Such an idea led to the appearance of his most famous book 'Foundations of Chemistry' ('Osnovy Khimii'). This two-volume handbook was printed stepwise (two issues of the first volume in 1868–1869, and the rest in 1871), survived 13 editions (8 during his life) and was later translated into German, English and French. Every new edition was expanded and deepened by the author. With no doubts, work on this book (and its further

† This text has been prepared on the basis of the materials by Dr. E. Babaev. For the full version of Mendeleev's biography, see the paper by E. Babaev available from the website of Mendeleev Communications (http://www.mendcomm.org/Mendeleev.aspx).

permanent improvements) was the main reason for the discovery and future development of the Periodic System.

The handbook started from the common organogen-elements (H, O, N and C) and their combinations, and the further plan was clear: halogens – alkali metals – alkaline earths. However, the plan for next chapters was less clear: where to put and how to order heavier elements? Trying to avoid any arbitrary order, Mendeleev noticed patterns in the properties of several families of light elements, arranged in the order of increasing atomic weights, and found a sort of periods:

Li = 7;	Be = 9.4;	B = 11;	C = 12;	N = 14;	O = 16;	F = 19
Na = 23;	Mg = 24;	Al = 27.4;	Si = 28;	P = 31;	S = 32;	Cl = 35.5
K = 39;	Ca = 40;		Ti = 50;	V = 51;		

He realized that this pattern could be applied to arrange heavier elements. As he wrote: ‘Li, Na, K and Ag relate to each other as C, Si, Ti and Sn, or as N, P, V and Sb’. However, the further task was complicated by the existence of triads (like Fe–Co–Ni, similar both in weights and properties), rare earths, unclear or wrong atomic weights *etc*. Nevertheless, Mendeleev printed first draft of the Periodic Table with all 63 known elements on March 1, 1869. (In that early version the rows of halogens and alkali metals were joined together to avoid emptiness in the middle of the table.) Most important was that he left places (like ? = 68, ? = 70) for unknown elements. On March 13, this small printout (150 copies in Russian and 50 in French) was sent to his colleagues.

In his further studies of 1869–1871, Mendeleev investigated the change of atomic volumes of elements and oxidation steps in their highest oxides (from R_2O to R_2O_7), which he proved to be periodic function of atomic weight. Finally, he realized the difference in the nature of odd and even periods (thus finding a place for triads) and drew a chart (short form of the Periodic Table) as it was later used in most handbooks.

The history and further development of the Periodic Law is well known. The strict law found by Mendeleev required not only changes of some known atomic weights but, more importantly, the existence of some yet undiscovered elements with certain atomic weight and properties. Three elements predicted by Mendeleev have been discovered during his life by European chemists:

Predicted	Found	Discovery details
eka-aluminium (M=68)	gallium (M=70)	1875, P. E. Lecoq de Boisbaudran
eka-boron (M=44)	scandium (M=45)	1879, L. Nilson
eka-silicium (M=72)	germanium (M=73)	1886, C. Winkler

The properties of gallium nearly matched those predicted by Mendeleev for eka-aluminium, except of the density; later de Boisbaudran re-measured the density and proved Mendeleev’s value.

Of course, the Periodic Table had several precursors and ‘cocursors’: Dobereiner (1829), Kremers (1852), Gladston (1853), Cooke (1854), Lenssen (1857), Pettenkofer (1858), Dumas (1858), Strecker (1859), Hinrichs (1867), Odling (1857, 1864), De Chancourtois (1862), Newlands (1865) and, of course, Meyer (1864, 1871). However, only Mendeleev realized that the Periodic Table reflects the law of nature (not just a convenient taxonomy), and only Mendeleev used it for successful prediction of unknown elements and for correction of atomic weights. L. Meyer, who strongly contributed to understanding the periodicity of atomic volumes, commented in the following way ‘It would be too hasty from so uncertain starting point to change accepted atomic weights’.

Although Mendeleev continued to popularize his discovery and update the book ‘Foundations of Chemistry’, since 1872 the topic of his interest dramatically changed to the physics of gases. In his theoretical studies, he re-examined the ideal gas laws and contributed to the equation $pV = nRT$ (Mendeleev–Clapeyron equation).

His scientific authority had grown not only in Europe (especially after the glorious story with gallium in 1875) but also in Russia. In 1876, he was elected to the St. Petersburg Academy of Sciences as a corresponding member. He frequently consulted the government and private business, and one of the topics was oil industry.

After 1871, Mendeleev’s interests also turned to the problems of higher education and fine arts.

In the early 1880 (soon after the discovery of scandium and the proof of its identity to eka-boron), Meyer initiated a disput on the question of the priority on the discovery of the Periodic System, and Mendeleev had to write an emotional respond.

In November 1880, Mendeleev tried to ballot to the full membership of the National Academy of Sciences without success (he got 9 votes against 10 in favor of F. Beilstein). The scientific community strongly protested against the decision of the Academy, and many foreign institutions and societies nominated Mendeleev as their full or honorary member. The Royal Society (London) awarded him a Davy medal (though jointly with Meyer).

His main chemical interest after 1882 was the theory of solutions. His early ideas on definite and indefinite compounds (from his magisterial and doctoral theses) now grew to the chemical theory of solutions, summarized in the monograph ‘The Study of Densities of Aqueous Solutions’ (1887).

In 1886, Mendeleev made two trips to Caucasus for the inspection of oil plants in Baku and suggested new ways of heavy oil utilization. In 1888, he examined the coalmines and plants in Donbass and suggested some key economic decisions (new credit and rent policies, canceling any plants taxation for a decade, favorable transportation tariff *etc.*).

Since 1889, as the member of the Governmental Council of Trades and Manufacturing, Mendeleev tried to arrange all possible tariffs in a sort of system. This result (known as the Mendeleev tariff) was published as a 700-page book.

After leaving the University in 1890, as a scientific consultant of the Navy ministry, Mendeleev received a new task of the development of smokeless gunpowder. He established a laboratory in St. Petersburg and during next two years succeeded to find a formula and to develop the technology.

In 1892, Mendeleev accepted the proposal to serve as a scientific keeper of the Bureau of Weights and Measures. Mendeleev was keen from this new service and performed a series of reforms in metrology. The small bureau was transformed into the Main Chamber, which soon became third in Europe (after France and Germany) center of excellence in metrology studies. First, he renewed the standards for traditional Russian units of mass (pound) and length (arshin and sazhen), made them from a special alloy (Pt–Ir) and calibrated in Paris. Then, he built an observatory and labs for studying the standards of other physical units (time, pressure, electric current, light, *etc.*), and in the later period explored the ways of their measurements with unbelievable accuracy.

He visited the Urals and wrote a book with the detailed plan of its industrialization. He thoroughly elaborated a programme of reforms in education with suggestions to cancel examinations. He collaborated with Navy and assisted to open the first ship-testing basin, although the ministry refused another his project – an icebreaker of his own design to explore Arctic. He wrote excellent popular chapters to the famous Encyclopedia by Brockhaus–Efron. Furthermore, Mendeleev combined all these activities with significant extension of his 'Foundations of Chemistry' (7th edition, 1903). He finally turned to the topics of demography, politics and the problems of society.

Mendeleev never received the Nobel Prize. After 1904, when the prize was given to Sir William Ramsay for discovery of noble gases – a new group in the Periodic System – chemists revived the interest to the system creator. Mendeleev was nominated in 1905, but the prize was given to Adolf von Baeyer. Mendeleev was nominated again in 1906, but the prize now was given to Henri Moissan. (Both times Mendeleev was second on the list.). The third consideration of his name as a nominee was interrupted by his death from influenza on February 2, 1907. Streets were crowded. The funeral procession was headed by students who carried big Periodic Table. In the same year, in memory of the great scientist, the Mendeleev Congress on General and Applied Chemistry was held in St. Petersburg. Afterwards, the Mendeleev Congresses, as the most prestigious national chemistry forums in this country with worldwide participation were held every 4–5 years. The last XVIII Mendeleev Congress, dedicated to the centenary of Mendeleev Congresses, was held in Moscow in September 2007 and became the largest and most representative during its century-long history.

Mendeleev's Periodic Table has promoted the discovery of new elements and the development of chemical science as a whole. In 1955, Glenn T. Seaborg *et al.* synthesised an element with the atomic number 101 and named it Mendelevium (Md) in recognition of the pioneering role of the great Russian chemist.

Being improved and enriched with new data as the science advanced, Mendeleev's Periodic Table has retained its basic principles and structure, which proves once more its fundamental nature.

The most recent results on evolution of Mendeleev's Periodic System were obtained by Professor Yu. Ts. Oganessyan and his co-workers (*Mendeleev Commun*., 2005, 1) at the Joint Institute for Nuclear Research, Dubna, Moscow Region, Russia. On the basis of fusion reactions of accelerated ionised ^{48}Ca nuclei with target nuclei, thirty-five isotopes of new chemical elements with atomic numbers from 104 to 118 have been synthesised. The half-life of some of them is up to 30 h (depending on the number of protons and neutrons in the nuclei) that gives the experimental proof of the existence of an 'island of stability' and the possibility to perform their chemical identification and study their chemical properties. The results obtained provide the first experimental confirmation of relativistic effects on the properties of elements in Mendeleev's Periodic Table.