Dmitri Mendeleev (1834–1907) – Creator of the greatest table of elements

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Dmitri Mendeleev, born in Tobolsk Siberia, Russia in 1834, is one of the legends of chemistry. The periodic table that he published in 1869 was the first successful effort to organize the then known elements in the form of a table.

The periodic table of elements is considered to be the most important man-made table. It is most appropriate that we recount life story of the great man who was responsible for this table. His life was one of agony and ecstasy. He overcame a traumatic period of poverty and tragedies and rose to become one of the greatest chemists of all time. His two defining characteristics were love for teaching and love for his countrymen. He had a larger than life personality and lived life on his terms.

MENDELEEV'S remarkable journey through life straddled two distinct phases. The first phase was marked by poverty, deprivation and tragedies. It lasted from his birth in 1834 to 1856.

Dmitri Mendeleev, the youngest of 17 children, was born on 7 February 1834 in Tobolsk, Siberia (Russia). His father Ivan Pavlovich was a teacher at a local gymnasium and mother Maria a home maker. She belonged to a well to do family of glass makers. Dmitri had a traumatic childhood. His father went blind soon after Dmitri's birth and lost his job. He died from tuberculosis when Dmitri was thirteen years old. The family pension was inadequate to provide even basic needs to her impoverished family; this forced Maria to take up the management of a rundown glass factory owned by her brother. As Dmitri was too young to be left at home, Maria took him with her to the glass factory. It became Dmitri's first school and his mother first teacher. He learnt three valuable lessons there: love, beauty and science were important in life. Dmitri was guided by these throughout his life.

When Dmitri turned 14, he joined the gymnasium in Tobolsk. He was an ordinary student. He enjoyed science, but disliked Latin. Dmitri often declared that the world could do without Plato, but even a dozen Newtons were insufficient. But Maria was convinced that her son's destiny was in science and she was determined that Dmitri should get a good university education in Moscow or St Petersburg. She diligently saved money for this.

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Just when things were settling down, a major fire destroyed the glass factory. The only money available to feed the family was what Maria had saved for Dmitri's education. Undeterred by this setback, Maria decided to move to Moscow with Dmitri and his sister to seek admission for Dmitri at the Moscow University. They trekked ~1600 km to Moscow as they could not afford transportation. Unfortunately, Dmitri failed to get admission there as he failed in Latin. Maria refused to give up.

They resumed their journey to St Petersburg where Dmitri was admitted to the Pedagogical Institute of Natural Sciences in 1850 where his father had trained as a teacher. Soon tragedy struck. This time it was a body blow. Within a week of his joining the institute, his mother succumbed to tuberculosis. Maria's dying words to her son were: always to refrain from illusion, insist on work and not words and to patiently search divine and scientific truth. His sister died soon after. For the first time in his life, Dmitri Mendeleev was alone, far away from home in an unfamiliar city. He did to not let this personal tragedy distract him from his goal and graduated at the top of his class. He showed the same grit when he was diagnosed with tuberculosis and his doctors gave him only two years to live unless he moved to warmer climate immediately. He was determined to get well and make his mother's dream for him come true. Mendeleev moved to the Crimean Peninsula in 1855 and taught science in a gymnasium at Simferopol for a year. On returning to St Petersburg in 1856, Mendeleev obtained his master's degree his for thesis 'Research and theories on expansion of substances due to heat'. He dedicated his work to his mother with these words *This investigation is dedicated to the memory of a mother by her youngest son ... she educated me by her own word, she instructed by example, corrected with love, and in order to devote me to science, she left Siberia with me, thus spending her last resources and strength*[1]. This marked the end of phase one and his tribulations.

1859, Turning point

The year 1859 marked the turning point in Mendeleev's life. He was deputed for two years to study the scientific and technological advances made in the laboratories in France and Germany. Mendeleev believed that there was

neither talent nor genius without hard work. He made full use of the deputation to visit and work in various laboratories in France and Germany doing research on several topics. He attended the first International Chemistry Congress held in Germany in 1860 where he interacted with leading scientists of Europe and America. One of the far reaching decisions taken at the conference was to fix the atomic weight of HYDROGEN as 1, as it was the lightest element.

Mendeleev returned to Russia in 1861 determined to implement the advances he had studied abroad. He joined as a teacher of chemistry at the Technological Institute in St Petersburg. When he found the available textbook inadequate, he wrote the textbook *Organic Chemistry* in just 61 days. He was only 28 years old. It won him the prestigious Demidov Prize. Young Mendeleev had arrived on the Russian scientific scene with a bang. He travelled extensively by overcrowded trains to use scientific discoveries to advance Russia's economic development. His long-term commitment to modernize petrochemical industry was inspired by a visit to the Baku oilfields in 1863.

Mendeleev obtained his doctorate degree for his thesis 'On the combinations of water with alcohol' in 1865 and became Professor of Chemistry at the University of St Petersburg in 1866. As professor of chemistry, he had to teach inorganic chemistry and as no satisfactory Russian textbook was available, he decided to write 'Principles of chemistry'. The unexpected outcome of this decision was the creation of his magnum opus *The Periodic Table*.

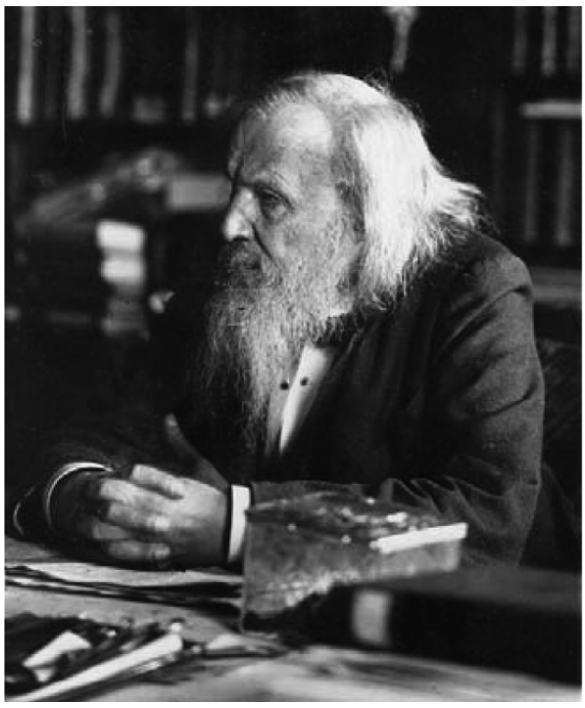


Figure 1. Dmitri Mendeleev (Wikipedia Public Domain).

Periodic table: From a sketch to an enduring masterpiece (Figure 2)

Mendeleev was convinced that there was an inherent order in the way the elements were arranged. He strongly believed that *Nothing from mushrooms to a scientific dependence can be discovered without looking and trying*[2]. He was an avid player of the card game, Solitaire. Mendeleev in an inspired guess was convinced that the horizontal and vertical arrangement of the four suites of would provide the solution.

He prepared a pack of cards (Figure 4) of the then known 53 elements. The card of each element had its atomic weight and some important properties.

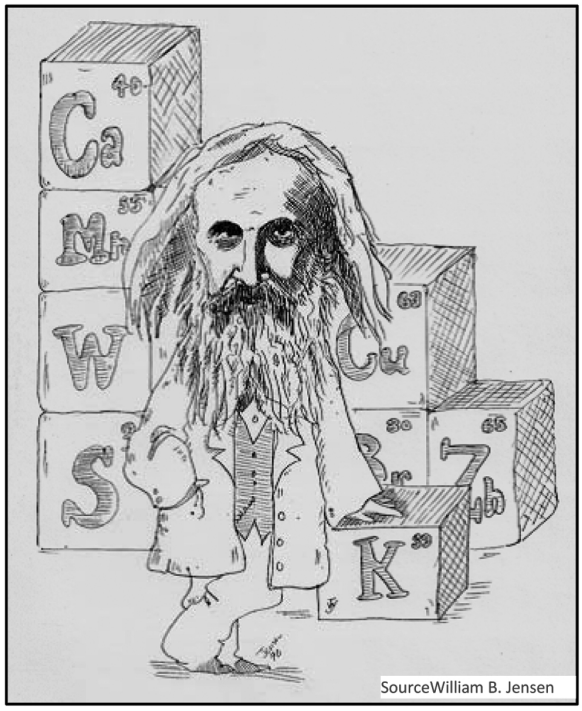


Figure 2. Sketch of Mendeleev by William B. Jensen. From *Chymists That Strange Class of Mortals*.

Figure 3. Four suites of cards pack.

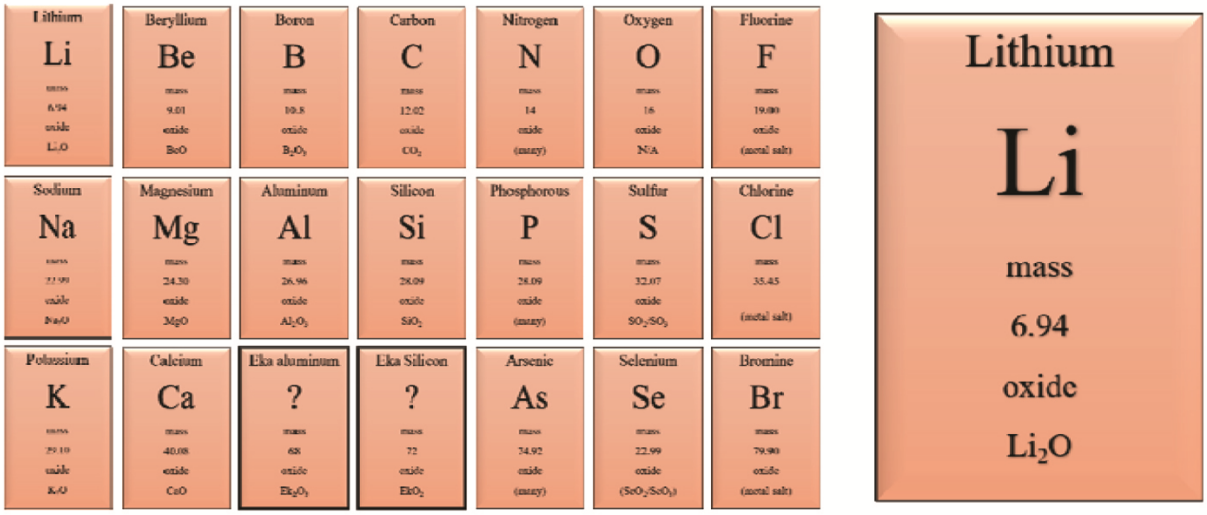


Figure 4. Horizontal and vertical arrangement of Mendeleev's cards of elements.

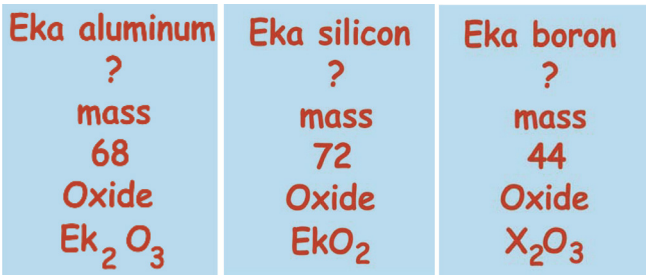
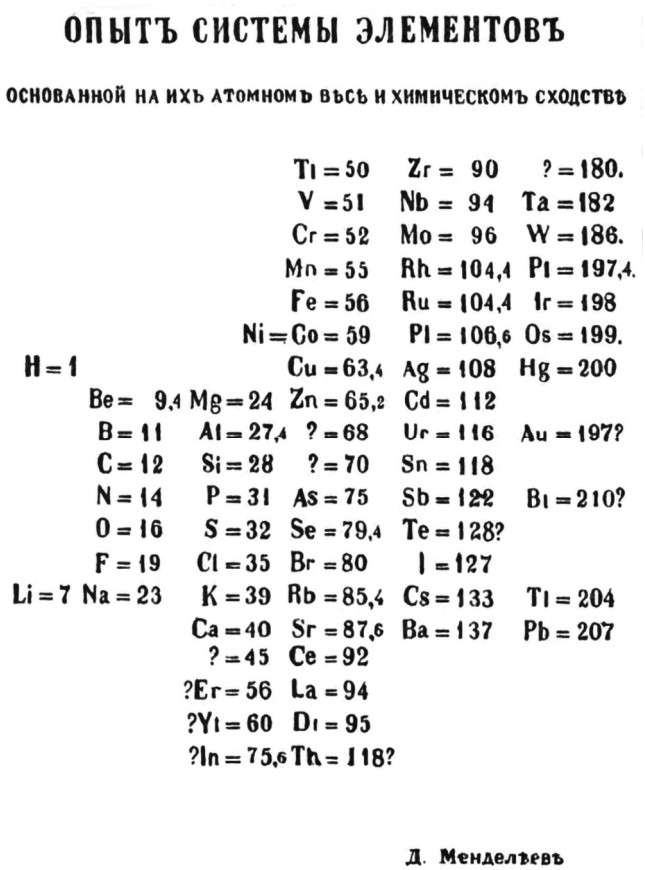


Figure 5. Eka-aluminum, Eka-silicon and Eka-boron.

Mendeleev played 'Chemical Solitaire' with his cards pack of elements constantly (sometimes going without sleep for 3–4 days) changing the position of the cards to find the correct position for each of the known 53 elements (Figure 4).

He arranged elements horizontally in an ascending order of their atomic mass. He labelled the rows 'periods' and each period had 7 elements. When he arranged all the cards, he noticed that in the vertical columns (which he labelled groups), the first element of the next row had similar properties as the first element in the previous row. However, the pattern of properties repeated themselves only when he left some gaps in the table.

Before he created the periodic table, *the chemical elements were mere fragmentary, incidental facts in nature; there was no special reason to expect the discovery of new elements*[3]. Finally, after years of struggle he was able to unravel the basis of the inherent relation among the existing elements. The uniqueness of the arrangement is the spaces left blank for the yet to be discovered elements. In a flash, Mendeleev realized that these elements existed but were yet to be discovered. Based on the properties of the previous and following elements, he predicted their properties.


ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ

			Ti = 50	Zr = 90	? = 180.	
			V = 51	Nb = 94	Ta = 182	
			Cr = 52	Mo = 96	W = 186.	
			Mn = 55	Rh = 104,4	Pt = 197,4.	
			Fe = 56	Ru = 104,4	Ir = 198	
			Ni = Co = 59	Pl = 106,6	Os = 199.	
H = 1			Cu = 63,4	Ag = 108	Hg = 200	
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112		
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?	
	C = 12	Si = 28	? = 70	Sn = 118		
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?	
	O = 16	S = 32	Se = 79,4	Te = 128?		
	F = 19	Cl = 35	Br = 80	I = 127		
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204	
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207	
		? = 45	Ce = 92			
		?Er = 56	La = 94			
		?Yt = 60	Di = 95			
		?In = 75,6	Th = 118?			

Д. Менделѣевъ

Figure 6. Mendeleev's first periodic table 1869 in Russian. From Wikimedia Commons.

He called the missing elements Eka-aluminum, Eka-silicon and Eka-boron (Figure 5). Eka-aluminum-gallium was discovered by the French chemist Paul-Émile Lecoq de Boisbaudran in 1875, Eka-silicon, germanium was discovered by the German chemist

Clemens Winkler in 1876 and Eka-boron, Scandium was discovered by Lars Frederick Nilson in 1876. (Mendeleev was a Sanskrit scholar. Eka in Sanskrit means first.)

Mendeleev summed up his observations thus: *If all the elements are arranged in the order of their atomic weights, a periodic repetition of properties is obtained. This is expressed by the law of periodicity*[2].

The first version of his historic periodic table titled 'The dependence between the properties and the atomic weights of the elements' was presented to the Russian Chemical Society in 1869 by his colleague as Mendeleev was too ill to present it himself.

The 35-year-old Mendeleev became a celebrity over night but this had a flip side. It eclipsed his true genius. Mendeleev was a polymath. He was a Renaissance man in the mold of Leonardo da Vinci. Besides being one of the most outstanding chemists of all time, he was an excellent physicist, metrologist, economist, meteorologist and geologist. He was one of the first to understand the origin of petroleum deposits. He often proclaimed *Burning petroleum as fuel would be akin to firing up a kitchen stove with bank notes*[4]. He was also a builder. He built Arctic ice breaker, aerostat machines, made quality suitcases. He was the first to suggest transporting oil by pipelines.

The two qualities that set Mendeleev apart were his love for teaching and love for the long-suffering fellow compatriots. On his long journeys across Russia by overcrowded trains, he enjoyed teaching farmers newer and better ways of farming as much as teaching in the university in well-equipped classrooms. Mendeleev was a man of principles and great courage and an outspoken liberal. He resigned his professorship in 1890 as he did not agree with the government's harsh suppression of student protests. While this display of solidarity with the students was applauded by them, the officialdom was hostile. Mendeleev had a larger than life personality and was unconventional in his private life. Even in the Tsarist Russia, he set his own rules and lived life on his own terms. It is said he trimmed his beard and hair once a year in spring and did not change this custom even for an audience with the Tsar. Again, he defied the Russian Orthodox Church by marrying without waiting for the stipulated seven year gap after his divorce from his first wife and was accused of bigamy. When the clergy complained to the Tsar of Mendeleev's defiance of the law of the church, apparently Tsar ended the argument by saying 'Mendeleev's has two wives, yes, but I have only one Mendeleev'[5].

Mendeleev received many honours for his outstanding contributions to science. He received the Davy Medal and the Copley Medal of the Royal Society, London. He was elected to The Royal Society, London, The Swedish Academy of Sciences and The American Philosophical Society. Artificial element 101 is named Mendelivium in his honour. He was unlucky to miss the 1906 Chemistry Nobel Prize and he died the following year.

Mendeleev died on 20 January 1907 listening to his beloved wife Anna reading Jules Verne's *Journey to the North Pole*.

Mendeleev's words delivered in his last lecture at the University *There is nothing in this world that I fear to say. No one nor anything can silence me … . This is the feeling of man. I want you to have this inner freedom. It is my responsibility to help you to achieve this inner freedom*[6] are the best tribute for this truly remarkable and multifaceted colossus.

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