A BRIEF HISTORY OF THE PERIODIC TABLE

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CHAPTER 1

THE PROPHET OF THE PERIODIC TABLE

The Discovery

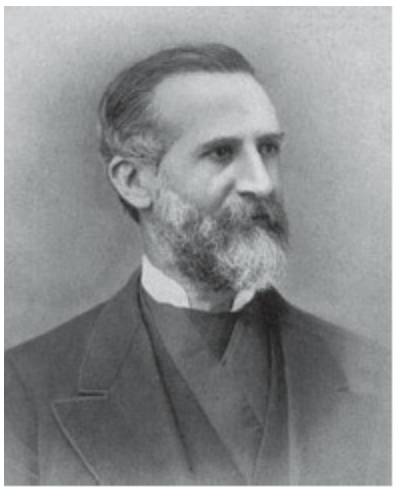
“There is an element as yet undiscovered. I have named it eka-aluminium by properties similar to those of the metal aluminium. You shall identify it, seek it, and it will be found”. The voice was prophetic. It was the epoch making year 1869. The prophetic voice was from a young enthusiastic and ebullient professor of chemistry of the St. Petersburg University, Russia, Dmitri Ivanovich Mendeleev. Many were sceptics. You can discover a new star in the heaven, but not a new element on Earth—was their comment. The 63 elements then known were complete and comprehensive.

From a byzantine heap of facts collected over a period of 20 years, from all over the world the youthful, erudite and diligent creature, Dmitri Ivanovich Mendeleev was in search of an arrangement of elements with predictable properties. Chemistry was then in a weird state. Enormous source of compounds with diverse properties were known. Elements themselves differed in their properties widely. Oxygen, hydrogen, nitrogen chlorine were gases. Mercury and bromine were liquids under normal conditions. Metals like platinum and iridium were hard. Sodium and potassium were soft. Lithium was so light that it could float on water. Copper was red and gold was yellow; iodine was steel grey in solid and violet in vapour state. Phosphorus was white and bromine red. Metals like nickel and chromium could be dazzlingly polished while lead and aluminium were dull. Gold never tarnished in air where as iron could rust easily in presence of water. Elements like potassium and fluorine were so reactive that they were dangerous to handle. Combination of elements with oxygen, available in abundance in the air, was strange. Some combined in the atomic ratio 2:1; some 1:1; some 2:3 and some with irregular stoichiometry. The list is endless. Scientists got lost

in the maze of the corridors of chemistry.

While the world was rumbling with the first prophecy, the Russian sage predicted the existence of another element eka-boron. Eka in Sanskrit means one. It was immediately followed by the prediction of the existence of a third element unknown to the world, eka-silicon. He boldly predicted several of its properties.

Scientists went after the search for the missing elements this Russian had predicted. In 1875 the first of these elements eka-aluminium was discovered in a zinc ore, obtained from the Pierrefitte mine in the Pyrenees by the French man Lecoq de Boisbaudran. Lecoq very carefully analysed the mineral and examined the new element with extreme diligence and patience. Lecoq was professionally competent in spectroscopy. He examined the element by spectroscopy and captured the unfamiliar violet line confirming it to be a new element. The new element possessed properties exactly as predicted by Mendeleev. The element easily fused, formed alloys, its chloride was volatile as predicted by the Russian. Lecoq named it gallium after the ancient name of his native country France. It was a miracle. Sceptics did not believe it or at least agreed it to be chance discovery. Mendeleev, the philosopher, was stirred when the news reached St. Petersburg. This was the first victory of Mendeleev's periodic law.



Lecoq de Boisbaudran

Per Teodor Cleve

Lars Fredrik Nilson

(Reinforcers of the Periodic Law)

In 1885 came the most brilliant triumph of Mendeleev when the German

chemist Winkler discovered another new element in a silver ore (argyrodite-Ag_8GeS_6) from the Himmelsfuerst mine that matched eka-silicon. It was a dirty gray element with an atomic weight 72.73, density 5.47, slightly reacted with acids leaving no scintilla of doubt about Mendeleev, second prophecy; the discovery dumbfounding the sceptics. Winkler gave it the name germanium.

Two years later the great victory followed. Two Scandinavian scientists Nilson and Cleve discovered another element from the rare mineral gadolinite $(Ce, La, Nd, Y)_2\ FeBe_2Si_4O_{10}$. They gave it the name scandium. The whole world acknowledged the periodic law enunciated by Mendeleev.

The Early Childhood and Education

Dmitri was born on February 7, 1834 in Siberia, USSR. He was the last of the siblings of a family of seven children. When Dmitri was young, his family was overtaken by misfortune. His father was the director of a high school; unfortunately he became blind and soon died of consumption.

Maria Dmitrievna Mendeleeva and Ivan Pavlovich Mendeleev

His mother was a Tartar beauty. She became unable to run the family with the meagre pension she received. She reopened the junk glass factory her family had established in Siberia. Then Tobolsk was the administrative

headquarter to which Russian political exiles were sent. One of these prisoners was married to the sister of Dmitri who offered him some rudimentary lessons on chemistry. In the mean while the glass factory was destroyed by fire that dried up all the income Dmitri's mother had. However she was determined to give Dmitri good education to uphold the dignity and tradition of the ancestors. Dmitri was also the darling eye of his mother. She was already fifty seven. She took Dmitri to Moscow with the hope to admit him to a good school, which could not be possible due to official red tapeism. Determined Maria that her son would get good education she undertook the journey to St. Petersburg where Dmitri could finally get admittance to the department of science in a pedagogical institution. Here Dmitri received training for a High School teacher. He had his specialization in mathematics, physics and chemistry. Somehow he had no taste for classical literature or philosophy. In later years he revealed that the world can wait for a Pluto, but it needs twenty Newton's to meet the needs of the world. Dmitri was diligent and through hard work graduated from the school at the head of his class.

During his early days Dmitri was always a frail person and never enjoyed a good health. During his studies at the high school his health got deteriorated and the news of his mother's serious illness, completely unnerved him. He went to see his mother while she was in her death bed. She gave her a piece of advice to lead him in his future course of life: "Refrain from illusions, insist on work and not on words. Patiently search divine and scientific truth." Dmitri never forgot his mother's advice. He always dreamed that he stood on a solid earth.

Because of his falling health his physician advised him to move to a warmer climate. He left for the south Russia and got a position as a science teacher at Simferopol in Crimea. When the Cremean war broke out he moved to Odessa. At the age of twenty two he returned to St. Petersburg and worked as a private-docent to teach without any remuneration. Within a few years he requested for permission to go to France and Germany to pursue higher studies and was granted the same. In Paris he joined Henri Regnault and after a year went to Heidelberg then an active centre of scientific research. Here he met Bunsen and Kirchoff from whom he learned spectroscopy. He along with Kopp went to attend the Science Congress of Karlsruhe and listened to two of the most important emerging areas of chemistry namely the Avogadro's molecular theory and Cannizarro's atomic weight. The two great ideas were

to do valiant service to Dmitri in his immediate scientific research.

Amedeo Avogadro

Kirchoff and Bunsen

Stanislao Cannizzaro

The following two years were the busiest period of his life. He was married to Feozva Nikitchna Leshcheva. He wrote a text book on **organic chemistry** within a period of two months which earned him great reputation besides being honoured with The Demidov Prize. He obtained his doctorate in chemistry for his research on **"The Union of Alcohol with Water."** He was a teacher par excellence, a great thinker and a competent experimenter. Soon he earned great reputation and was appointed as a full professor of chemistry by the St. Petersburg University before he attained thirty two years of age.

The Epoch making year

Ancient artisans knew gold, silver, copper, iron, mercury, lead, tin, sulphur and carbon. Alchemists had discovered some more elements in their vain search of the philosopher's stone to convert base metals into gold and to find the elixir of life. Alchemists by their habit were nasty and obnoxious. But they were the people who gave direction to the future course of chemistry. They devised many types of glass wares which are used even today by the chemists without any change. Brandt, the alchemist, discovered the glowing phosphorus in human urine.

The year 1869 was an epoch making year. After twenty years of collecting experimental data, reading voluminous papers, arranging and rearranging the chemical elements, Mendeleev presented his epochal paper "On the relation of the properties to the atomic weights of the elements" before the Russian Chemical Society on 27th of February, 1869. The periodic table was born. His

contribution to humanity overwhelmed the whole scientific world. The discovery of the periodic table for classifying elements represents the culmination of a number of scientific developments rather than springing from an individual's effort.

The Kernel of this discovery had not germinated overnight. Mendeleev admitted that the law was the direct outcome of the stock of generalization of established facts which has accumulated by the end of the decade 1860–70.

Around the time Mendeleev developed the periodic table in 1868, Julius Lothar Meyer of Germany while revising his chemistry book in 1868 also predicted a periodic table remarkably similar to Mendeleev's but his work was published in 1870 due to publisher's delayed action. This fact led to acrimonious dispute for priority. But Mendeleev had sufficient confidence in his table and devoted his lifetime to several new elements and the properties of their compounds. The most important of Mendeleev's discovery of chemical periodicity is that it elevated his discovery to a law of nature and spent his life defending its validity.

The after Glow

In 1894, Sir William Ramsay and Lord Rayleigh discovered the element argon and within the next few years, Ramsay announced four other new elements helium, neon, krypton and xenon. In 1900, the German physicist Friedrich Ernst Dorn (1848–1916) discovered radon. These are known as Noble gases. The name 'Noble' derives from the fact that the gases seem to stand apart from other elements, rarely interacting with them to form compounds. Originally, Mendeleev's table did not have a provision to place such inert gases. However, physicist successfully incorporated the noble gases to the table in a new arrangement. They introduced an additional column between the halogens and alkali metals.

In Mendeleev's table the second point of contention was regarding the precise ordering of the elements that involved the atomic weights. In 1913, the Dutch amateur Anton von den Broek, a theoretical physicist suggested the ordering principle lay instead in the nuclear charge of each atom.

Henry Moseley, working at Manchester University tested this hypothesis in 1913 shortly before World War I. Mosley began by photographing the X-ray spectra of 12 elements, 10 of which occupied consecutive places in the

periodic table of Mendeleev. He discovered that the frequency features called k-lines in the spectrum of each element were directly proportional to the sequence of integers representing the position of each successive element in the periodic table. In 1920, Rutherford referred to this fundamental quantity as atomic number of the element. Atomic number replaced the atomic weight of the periodic table and revealed the details of the properties of each elements and their position in the periodic table.

Mendeleev died in the year 1907. He didn't live to see the crowning glory the Manchester boy brought into his periodic table. By the time of his death 86 elements were known and accommodated in the periodic table. Scientists searched for new elements in every nook and corner of the earth and found 92 elements occurring terrestrially and the following 26 elements with atomic numbers 93 to 118 have been artificially made by man and put them into their right places in the periodic table.

Periodic table remains at the heart of the study of chemistry. It remains as one of the most fruitful and fundamental iconic idea in modern chemistry and its future developments. The only comparable discovery may be made to Darwin's theory of evolution. Unlike Newtonian mechanics, which had been falsified, the periodic table stands strong and integral to the study of chemistry.

Awards and Honours

He was recognized by the world for his everlasting discovery and many honours are showered upon him. The University of Moscow made him one of its honorary life members. The Royal Society of London awarded him the Davy medal which was shared with Lothar Meyer. Lothar Meyer was recognized along with Mendeleev as one of the pioneers and independent investigators of the periodic table. The English Chemical Society honoured him with the coveted Faraday medal. Along with the medal he was handed an honorarium in a purse of Russian national colour which Mendeleev renounced declaring that the society had shown him a rare respect of inviting him to do honour to memory of Faraday in a place made sacred by his path breaking and momentous research and contributing invaluable service to humanity. Besides chemical societies of Germany and America, universities of Princeton, Cambridge, Oxford and Gottingen presented him with decorations and honours.

Mendeleev as a Social Reformer

Besides being one of the genius and natural philosophers, Mendeleev was also a social reformer. He broke away from the conservative and male chauvinistic attitude of Russians towards women and regarded them as equals in their struggle towards education and work. Though Mendeleev hesitatingly believed that women were naturally and mentally inferior to men, he admitted them to his lectures at the university and offered them employment in his office.

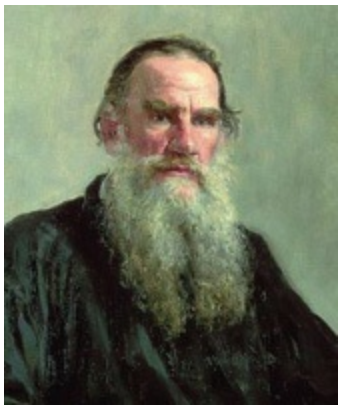
Mendeleev married twice. His first marriage was with Feozva Nikitchna Leshcheva in 1863 who was the daughter of a Russian poet. She bore him two children, the son Volodya and daughter Olga. The couple had an unhappy life. Mendeleev occasionally suffered from fits and tempers which could not be understood by Feozva. The marriage ended in divorce in the year 1882. Then Mendeleev was madly in love with Anna Ivanova Popova, a Cossack beauty, who was of artistic temperament. Then Mendeleev was 47 year old while Anna was 23 years younger to him. Anna was understanding in nature and was aware of the excellent erudition of Mendeleev and patiently bore all his flights, fancy and selfishness. She bore him four children, two sons Ivan, Vassili and two daughters Lyubov and Maria.

Feozva Lescheva

Anna Popova

Leo Tolstoy was his icon and ideal. Fearlessness and truth were the guiding force in all his actions. Like Tolstoy, Dimitri was dressed in loose garments which Anna had sewn for him. Dimitri had a handsome and impressive face partly covered with a long milky white beard. He had a fascinating personality and enjoyed the company of his guests. He loved books of

adventure. His favourite authors were Fenimore Cooper and Lord Byron. He loved music and paintings. Anna made pen-pictures of many great personalities of science like Lavoisier, Newton, Galileo, Faraday and Dumas which decorated Mendeleev's study.



During Mendeleev's time the Czarist Russia was brutal and tyrannical. The officialdom used their power and authority over people in unfair and cruel ways. Political dissidents were sent into exile into frozen Tobolsk in Siberia. Mendeleev was aware of the cruelty of the feudal society. It had already been stated that he received his preliminary lessons in Tobolsk from such a prisoner. Dmitri had the deep feeling of being extremely sorry for the wrongs to upright and honest people and openly objected to the officials for their wrong doings. However the officials were careful in their dealings with Mendeleev because services of Mendeleev were of much greater value to the country than the political unrest.

He always travelled in third class and engaged himself in intimate discussion with peasants, common man and small traders and learned from them the magnitude of hatred they harboured against the officialdom for their remorseless oppressive and high handed action and espionages. Mendeleev could not keep himself silent over the tyranny and the dictatorial behaviour of the Czarist Russian officials and strongly denounced them. On several occasions his scientific genius became the cause of political agitation when he was promptly sent to distant places on some government commissions.

Mendeleev had offered valuable service to Russian empire by carefully exploring the oil fields of Baku in Caucasus. There was an everlasting flame from a gap in the rock at Baku which was then one of the most valuable oil districts of the world. Local people were used to collect the oil from the

springs around Baku to light their homes.

In 1876 Mendeleev was sent to Pennsylvania, USA to make a study of the oil fields and exploration and extraction of technology. On his return from America he was sent to south Russia to investigate the Naphtha springs. Apart from his official mission he set up a laboratory and developed new method for commercial exploitation of the Naphtha products. He made extensive investigations on the banks and basins of Donetz River and opened it to the world for commercial purpose. He was an exponent of industrial development of Russia.

Mendeleev though a gifted scientist, sometimes clung to scientific speculation on intangible matter. Mysticism of ether, the fifth element of Aristotelian philosophy appeared to him real. He believed it to be omnipresent and pervade the whole world. He speculated it to be a material object belonging to the noble group of elements having mass million times smaller than hydrogen.

The Russo-Japanese war broke out in 1904. Mendeleev threw himself as a true nationalist and patriot in the war effort and was made advisor to the navy. During this period he invented pyro-collodion which was a new kind of powder without emitting any smoke. The Russian fleet was destroyed in the strait of Tsushima and Russia was defeated.

The grief due to Russia’s defeat hastened his end. He died in 1907 while reading Jules Verne’s Journey to the North Pole. The munificent and multi-faceted personality ended his seventy years of journey from a mortal man to an immortal scientist.

In 1957 the Russian Government released a postal stamp to commemorate 50^{th} year of his death. The communities of scientists have honoured him by naming a trans-uranium man-made element, atomic number 101, Mendelevium. Many commemorative stamps, first day covers, coins and medals were issued in his name.

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