Fulfilling Mendeleev's Dream

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The remarkable discovery of periodicity in the properties of elements and the bold predictions made on the basis of his periodic table made Mendeleev a supreme patterner of chaos. He set the agenda for chemists as the curtain came down on the 19th Century. The gaps in his periodic table had to be filled. Mendeleev's periodic table in 1868 had only sixty three elements (*Figure* 1). Within a span of thirty years the number of elements known to man saw a 50% increase. Searching for elements was easier since the properties of unknown elements could be predicted. Reasonable places to prospect for the new elements could be guessed from the occurrence of neighboring elements. The credibility of the periodic table as a predictive tool was established beyond doubt. But Mendeleev was convinced that it needed improvement. He was right. Improvements were needed, but one had to wait for a better understanding of the structure of the atom to progress. What made Mendeleev so sure that his periodic table needed improvement? Perhaps it was the discovery of argon in 1894 that gave him an uneasy feeling. Were there other unknown groups? Remember, the initial version of the periodic table had no provision for the inert gases. The year 1898 proved to be a turning point. Ramsay was instrumental in discovering the three inert elements neon, krypton and xenon and the existence of the zero group or the inert group was confirmed. Argon was not an anomaly! It would take only two more years to discover radon, the next member in the series. It was an inert radioactive gas formed during the disintegration of radium. But to complete the inert gas group one

Figure 1. Periodic table according to D I Mendeleev, 1869.

			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	Pd = 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 = 35,5	Br = 80	J = 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?		

had to wait till the end of the century! The work of Rutherford and Bohr on the nuclear and electronic structure of atoms cleared the decks for the modern version of the periodic table.

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The fundamental significance of the number of protons in the nucleus was realized and it was evident that the serial numbers in the periodic table had greater importance than the atomic weight due to their relationship to the atomic number. It was around 1905 that the long form of the periodic table was introduced by Alfred Werner. This illustrated the relationship between the position of the elements in the periodic table and the electronic configuration much better. We should mention here that there were several attempts to improve the periodic table but none were as successful as the 'long form'. Except for the numbering system which needed improvement, something that would take nearly 85 years, the modern form of the periodic table was available even in 1905. The most popular and convenient form of the periodic table, the long form, provided essential guidance for chemists working in the maze of elements. Although it was Becquerel who discovered radioactivity, the work of Marie Curie and Pierre Curie illustrated its enormous potential. The race for discovering new radioactive elements was instrumental in ushering in more new elements. It was the golden year of 1898 when the Curies announced the existence of two new elements polonium and radium. In one sense searching for radioactive elements was easier due to the telltale radiation from the element. But handling them was more difficult. The extraction of a gram of radium from a ton of pitchblende in a leaky old laboratory stands out as one of the remarkable achievements of Marie Curie. It bore testimony to her indefatigable spirit, and the value of hard work and perseverance.

The discovery of almost all the naturally occurring elements signaled the end of one more era. The remaining elements were short-lived and were formed as products during the decomposition of heavier radioactive elements. A few prominent gaps in the periodic table were radioactive elements. The last member of the alkali metal series francium was discovered in 1939, and the last member of the halogen series astatine discovered in 1940.

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The discovery of technetium by bombarding Mo with deuterons started a new chapter in the history of the discovery of elements. Synthetic elements were possible! It was soon recognized that the nuclei had to be accelerated to very high velocities to give them adequate energy to combine and make heavier elements. The first particle accelerator was built in California and the Lawrence Berkeley Laboratory headed by Seaborg became the sole portal for new elements entering the periodic table. In 1969 however, Germany's Gesellschaft fur Schwerion Forschung GSI (Institute for Heavy Ion Research) came into being and the competition heated up.

Since there are only 'islands of stability' access to a powerful atom-smasher is not sufficient to discover new elements. One needs to choose the right elements having the right energies to collide with each other. Detecting the fleeting existence of these unstable elements before they decay to give known products is another problem to surmount. Perhaps the synthesis of element 118, the last element in the sixth row (chemists do not count H, and He as the first row!) of the periodic table will illustrate the difficulties.

Scientists at the Lawrence Berkeley laboratory at California bombarded lead $^{208}Pb_{82}$ with $^{86}Kr_{31}$ to give an atom of element number 118. However, only one in 10^{12} collisions was effective. So after eleven days of the experiment they could detect 3 atoms of the new element ununoctium. With a lifetime of milliseconds, the properties of this element cannot be determined. But thanks to the periodic table, one can safely predict that it would be a gas at room temperature and pressure. Scientists at Berkeley feel that element ^{118}Uuo might be on the edge of a new island of stability. It should be possible to make more new elements and maybe the seventh row of the periodic table could be started. However, the electronic levels in these systems would be so close to each other and the possibility of filling *g* orbitals would result in electronic configurations that might not be easy to predict. The Aufbau principle may not hold good and we might have reached the limits of the periodic table as a predictive tool.

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