2019: International Year of the Periodic Table

150 year Anniversary of Mendeleev's first periodic Table

History of the Periodic Table

1789
Antoine Lavoisier, now known as the "father of modern chemistry," publishes a list of 33 elements or "simple substances," as he calls them. Although his list includes things such as heat and light, it is a major departure from previous thinking about elements. For Lavoisier, an element represents the final stage of chemical decomposition. This view moves away from earlier metaphysical notions about the nature of elements and emphasizes what can be observed and measured.

1805
John Dalton, a Manchester schoolteacher and a Quaker, revives the atomic theory of ancient Greek philosophers, while making it quantitative. Dalton also provides a new list of elements, but includes the relative weights of atoms of each element compared with an atom of hydrogen, which is assigned a weight of one unit. This development provides a basis from which other chemists can begin to discern relationships between different elements and is an essential step in the development of the periodic table.

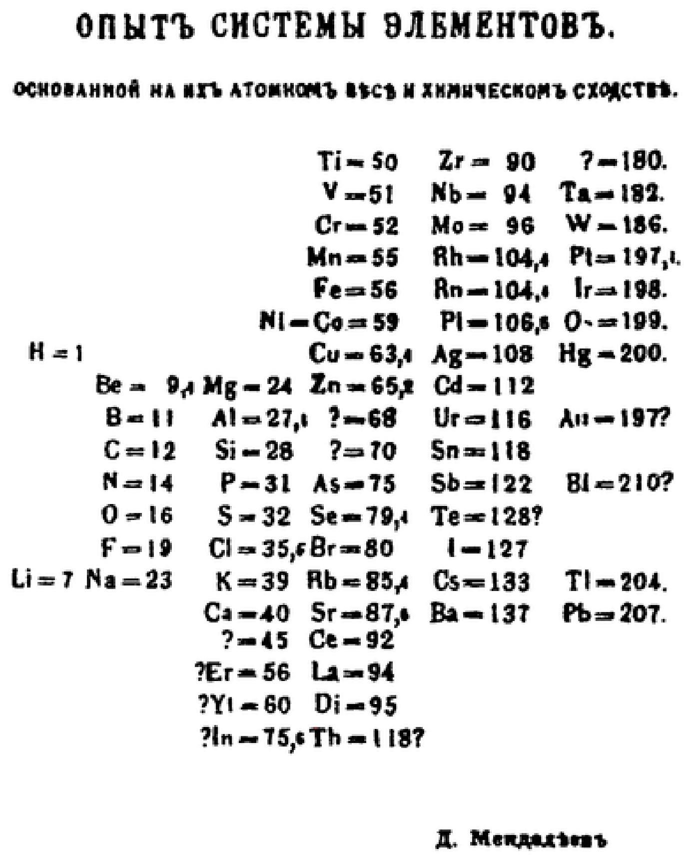
1829
Wolfgang Dobereiner, a chemist working in Jena, Germany, draws on John Dalton's atomic weights to discover triads, which are relationships among several groups of three elements whereby one of the three elements is the average of the two others in two respects. For example, a sodium atom has about the same weight as the averaged weights of lithium and potassium. Also, sodium's chemical reactivity is the average of lithium and potassium. Triads thus hint at mathematical relationships between different elements, representing a foreshadowing of the discovery of chemical periodicity.

1862-1867
Over a period of about five years, multiple scientists independently develop significant precursors to the periodic table. The first is French geologist Alexandre-Emile Beguyer De Chancourtois, who arranges the elements in a line in order of increasing atomic weight. This line is then arranged in a helical fashion, around a metal cylinder so that similar elements fall along vertical lines drawn along the length of the cylinder. Soon after, John Alexander Reina Newlands and William Odling, working independently in England, publish two-dimensional periodic tables, as does Gustavus Heinrichs, a Danish exile working in the United States. None of these systems receive much credit for a variety of reasons both scientific and sociological.

1868
Julius Lothar Meyer, a German chemist, publishes a number of periodic tables that represent the discovery of a fully mature table system. However, although he successfully accommodates most of the more than 60 then-known elements, Lothar Meyer fails to predict any new or missing elements, with one exception. He made a tentative prediction for the existence of a single element that he believed would have an atomic weight of 44.55. This element would eventually be discovered in Sweden and be named scandium. Its weight when first measured was 44.6.

1869
Dmitri Mendeleev, a Siberian by birth, working in St. Petersburg, Russia, publishes his first of many periodic tables and predicts the existence of four new elements that he provisionally names eka-aluminum, eka-silicon, eka-boron, and eka-manganese. Within fifteen years, the first three of these elements are discovered by other chemists and are called respectively gallium, scandium, and germanium, thus serving to solidify Mendeleev's reputation as the leading discoverer of the periodic table. The fourth of his initial predictions is synthesized in 1937 and named technetium.

Mendeleev's Periodic Table as first written out and then as published.



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=197,1.
			Fe=56	Rn=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=35,5	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

1894
William Ramsay and Lord Rayleigh, both working together in London, discover an unexpected and completely unreactive new element, a gas that they called argon. This discovery is followed by a further four additional unreactive gaseous elements. These discoveries initially present a serious threat to the periodic table because they cannot be accommodated into the periodic table. The problem is solved in 1900 by William Ramsay at University College, London, who creates a new

group of elements at the right of the halogen group. As a result, the periodic table not only survives this apparent threat, but gains further in credibility through being able to successfully encompass these new elements.

1895-1897
In three successive years, X-rays, radioactivity, and the electron are discovered, all of which have a profound impact on the study of the elements, the periodic table, and chemistry in general. X-rays lead to an experimental method to precisely identify each element. The discoveries of radioactivity and the electron show atoms are not indivisible as Dalton had supposed, but have a sub-structure. In 1900, Max Planck introduced his quantum of action. These discoveries together would soon explain why elements fall into groups on the periodic table.

1913-1914
In 1913, Niels Bohr working in Copenhagen publishes the first explanation of why certain elements fall into particular groups in the periodic table. This feature arises because of the analogous electron arrangements in concentric shells around the central nucleus of any atom. Between the years 1913 and 1914, Henry Moseley, in Manchester and later Oxford, establishes experimentally that elements are more accurately ordered according to an ordinal number, subsequently named "atomic number," than if ordered according to atomic weight, as had been the custom up to this point. Moseley's method also provides the means to uniquely identify any particular element, as well as indicating the number of elements that remained to be discovered between the naturally occurring elements from hydrogen ($Z = 1$) and uranium ($Z = 92$).

1937
The first artificially produced element is discovered in Palermo, Sicily, by Emilio Segre and coworkers. This element had been synthesized in a particle accelerator at the University of California, Berkeley, where Segre had worked, before being sent to Italy for analysis. This was to be the first of what are now about 30 artificially produced elements, including promethium ($Z = 61$), and astatine ($Z = 85$), in addition to 26 transuranic elements. The most recent discoveries of such elements are nihonium ($Z = 103$), moscovium ($Z = 105$), tennessine ($Z = 117$), and oganesson ($Z = 118$).

1939
The first transuranic element, synthesized at the University of California, Berkeley, by Edwin Mattison McMillan and Philip Hauge Abelson, is neptunium. This is followed by the synthesis of plutonium by Glenn T. Seaborg in 1941 in the same laboratory. Seaborg would contribute to the synthesis of a total of 10 such transuranic elements, including element 106, which is named seaborgium in his honor. He would also propose a modification to the periodic table that features the actinides as part of the f-block rather than as d-block elements. Similar arrangements were independently proposed earlier by Alfred Werner and Charles Janet.

2019
The periodic table is by no means a closed subject. Although it now stands complete for the first time since its discovery, attempts to synthesize elements 119 and 120 are being actively pursued. If discovered, these elements would form the beginning a new eighth period. In addition, debate continues over the placement of several elements, including the composition of group 3, and over whether there is an optimal form of the periodic table. A good candidate to fill this role might be Charles Janet's left-step table, which displays greater regularity than the conventional table, as well as being more in keeping with the presumed quantum mechanical foundations of the periodic table.

Charles Janet's left-step periodic table, 1929

																														1 H	2 He
																														2	2
																														3 Li	4 Be
																														8	8
																								5 B	6 C	7 N	8 O	9 F	10 Ne	11 Na	12 Mg
																								8	8	8	8	8	8	8	8
																								13 Al	14 Si	15 P	16 S	17 Cl	18 A	19 K	20 Ca
																								18	18	18	18	18	18	18	18
														21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	37 Rb	38 Sr
														18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
														39 Y	40 Zr	41 Nb	42 Mo	43 Ma	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 X	55 Cs	56 Ba
														32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
57 La	58 Ce	59 Pr	60 Nd	61 Il	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tu	70 Ny	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85	86 Em	87	88 Ra
32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
89 Ac	90 Th	91 Bv	92 U	93	94	95	96	97	58	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120

Periodic Table of the Elements

	1A 1	2A 2	3B 3		4B 4	5B 5	6B 6	7B 7	8B 8	9	10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H Hydrogen 1.008																		2 He Helium 4.003
2	3 Li Lithium 6.941	4 Be Beryllium 9.012												5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.18
3	11 Na Sodium 22.990	12 Mg Magnesium 24.305												13 Al Aluminum 26.981	14 Si Silicon 28.085	15 P Phosphorus 30.974	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956		22 Ti Titanium 47.867	23 V Vanadium 50.941	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906		40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium [98]	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.905	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.75	52 Te Tellurium 127.60	53 I Iodine 126.904	54 Xe Xenon 131.293
6	55 Cs Cesium 132.905	56 Ba Barium 137.327	57 La Lanthanum 138.905	*	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.966	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.98]	85 At Astatine [209.99]	86 Rn Radon [222.02]
7	87 Fr Francium [223.02]	88 Ra Radium [226.03]	89 Ac Actinium [227.03]	**	104 Rf Rutherfordium [261.11]	105 Db Dubnium [262.11]	106 Sg Seaborgium [266.12]	107 Bh Bohrium [264.12]	108 Hs Hassium [269.13]	109 Mt Meitnerium [268.14]	110 Ds Darmstadtium [271.15]	111 Rg Roentgenium [272.15]	112 Cn Copernicium [277]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [292]	117 Ts Tennessine [294]	118 Og Oganesson [294]

*	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
**	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium [237.05]	94 Pu Plutonium [244.06]	95 Am Americium [243.06]	96 Cm Curium [247.07]	97 Bk Berkelium [247.07]	98 Cf Californium [251.08]	99 Es Einsteinium [252.08]	100 Fm Fermium [257.10]	101 Md Mendelevium [258.10]	102 No Nobelium [259.10]	103 Lr Lawrencium [262.11]