

The Periodic Table of Elements

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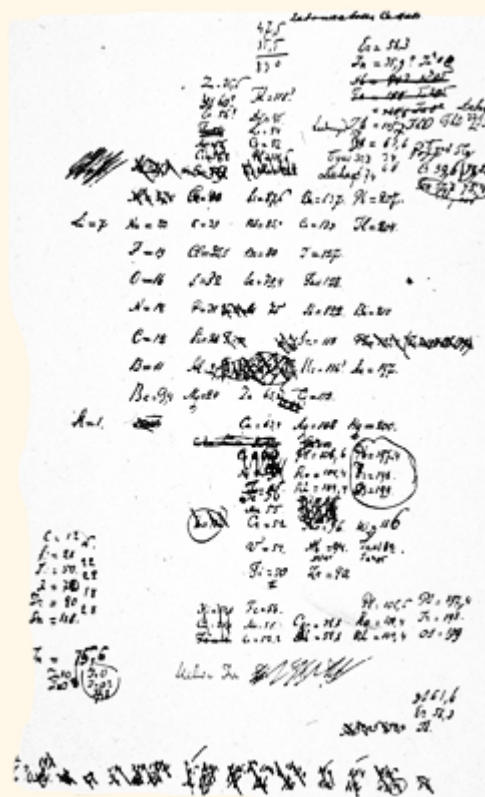
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➤ Dmitri Ivanovich Mendeleev (1834-1907)

WHO ORGANIZED THE ALPHABET? We will never be able to attribute to a single individual the development of the basic building blocks of writing. Yet we do know the name of the man who devised the method of classifying the basic building blocks of matter. Dmitri Ivanovich Mendeleev was born in Siberia in 1834. When Mendeleev became a professor of general chemistry at the University of St. Petersburg, he was unable to find an appropriate textbook and thus began writing his own. That textbook, written between 1868 and 1870, would provide a framework for modern chemical and physical theory.



Mendeleev first trained as a teacher in the Pedagogic Institute of St. Petersburg before earning an advanced degree in chemistry in 1856.



Mendeleev's first sketch of a periodic table of the elements

➤ Elements and Their Properties

COMBINATIONS OF 26 LETTERS make up every word in the English language. Similarly, all material things in the world are composed of different combinations of about 100 different elements. An element is a substance that cannot be broken down into simpler substances through ordinary chemistry--it is not destroyed by acids, for example, nor changed by electricity, light, or heat. Although philosophers in the ancient world had a rudimentary concept of elements, they were incorrect in identifying water, for example, as one. Today it is common knowledge that water is a compound, whose smallest unit is a molecule. Passing electricity through a molecule of water can separate it into two atoms of hydrogen and one atom of oxygen, each a separate element.

The ancient concept of elements jibed with today's in noting that elements had characteristic properties. Just as people not only look different from each other but also interact differently with others, so elements have both physical and chemical properties. Some elements form shiny solids, for example, that react readily and sometimes violently with oxygen and water. The atoms of other elements form gases that scarcely interact with other elements.

			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	
			Cu=63,4	Ag=108	Hg=200
H=1			Zn=65,2	Cd=112	
Be=9,4	Mg=24		?=68	Ur=116	Au=197?
B=11	Al=27,4		?=70	Sn=118	
C=12	Si=28		As=75	Sb=122	Bi=210?
N=14	P=31		Se=79,4	Te=128?	
O=16	S=32		Br=80	J=127	
F=19	Cl=35,5		Rb=85,4	Cs=133	Tl=204
Li=7	Na=23		K=39	Ba=137	Pb=207
			Ca=40	Sr=87,6	
			?=45	Ce=92	
			?Er=56	La=94	
			?Yt=60	Di=95	
			?In=75,6	Th=118?	

Mendeleev's table as published in 1869, with many gaps and uncertainties

Below: The table, rotated ninety degrees, as shown in textbooks in 1898 when Marie Curie discovered Radium. Mendeleev and others promptly added the new element to their textbooks. Its place is in column II below Ba, Barium. (From W. Ostwald, *Grundriss der Allgemeine Chemie*.)

0	I	II	III	IV	V	VI	VII	
He 4	Li 7	Be 9.1	B 11	C 12	N 14	O 16	F 19	—
	Ne 20	Na 23	Mg 24.4	Al 27.1	Si 28.4	P 31.0	S 32.1	Cl 35.5
Ar 40	K 39.1	Ca 40	Sc 44.1	Ti 48.1	V 51.2	Cr 52.1	Mn 55.0	Fe 56, Ni 58.7, Co 59
Kr >45	Cu 63.6	Zn 65.4	Ga 70	Ge 72	As 75	Se 79.1	Br 80.0	—
X >65	Rb 85.4	Sr 87.6	Y 89	Zr 90.6	Nb 94	Mo 96.0	—	Ru 102, Rh 103, Pd 106
	Ag 107.9	Cd 112	In 114	Sn 118.5	Sb 120	Te 127	J 126.9	—
	Cs 133	Ba 137.4	La 138 etc.	—	—	—	—	—
	—	—	—	—	—	—	—	—
	—	—	Yb 173	—	Ta 183	W 184	—	Os 191, Ir 193, Pt 195
	Au 197.2	Hg 200.3	Tl 204.1	Pb 206.9	Bi 208	—	—	—
	—	—	—	Th 232	—	U 240	—	—

SCIENTISTS HAD IDENTIFIED over 60 elements by Mendeleev's time. (Today over 110 elements are known.) In Mendeleev's day the atom was considered the most basic particle of matter. The building blocks of atoms (electrons, protons, and neutrons) were discovered only later. What Mendeleev and chemists of his time could determine, however, was the atomic weight of each element: how heavy its atoms were in comparison to an atom of hydrogen, the lightest element.

“I began to look about and write down the elements with their atomic weights and typical properties, analogous elements and like atomic weights on separate cards, and this soon convinced

me that the properties of elements are in periodic dependence upon their atomic weights.”

--Mendeleev, *Principles of Chemistry, 1905, Vol. II*

Periodic Table of the Elements

1 H																	2 He														
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne														
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar																								
19 K	20 Ca	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	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe														
55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	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 At	86 Rn
87 Fr	88 Ra	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	104 Rf	105 Ha	106 Sg	107 Nh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

* Lanthanide Series
+ Actinide Series

A modern periodic table.

Classifying the Elements

AN OVERALL UNDERSTANDING of how the elements are related to each other and why they exhibit their particular chemical and physical properties was slow in coming. Between 1868 and 1870, in the process of writing his book, *The Principles of Chemistry*, Mendeleev created a table or chart that listed the known elements according to increasing order of atomic weights. When he organized the table into horizontal rows, a pattern became apparent—but only if he left blanks in the table. If he did so, elements with similar chemical properties appeared at regular intervals—periodically—in vertical columns on the table.

Mendeleev was bold enough to suggest that new elements not yet discovered would be found to fill the blank places. He even went so far as to predict the properties of the missing elements. Although many scientists greeted Mendeleev's first table with skepticism, its predictive value soon became clear. The discovery of gallium in 1875, of scandium in 1879, and of germanium in 1886 supported the idea underlying Mendeleev's table. Each of the new elements displayed properties that accorded with those Mendeleev had predicted, based on his realization that elements in the same column have similar chemical properties. The three new elements were respectively discovered by a French, a Scandinavian, and a German scientist, each of whom named the element in honor of his country or region. (Gallia is Latin for France.) Discovery of a new element had become a matter of national pride—the rare kind of science that people could read about in newspapers, and that even politicians would mention.

Claiming a new element now meant not only identifying its unique chemical properties, but finding the atom's atomic weight so the element could be fitted into the right slot in the periodic table. For radioactive atoms that was a tough challenge. At first these atoms were isolated only in microscopic quantities. The straightforward way to identify them was not by their chemical properties at all, but by their radiations. Until the radioactive atoms could be sorted out with traditional chemistry, some scientists were reluctant to call them new elements.

WHAT MADE THE TABLE PERIODIC? The value of the table gradually became clear, but not its meaning. Scientists soon recognized that the table's arrangement of elements in order of atomic weight was problematic. The atomic weight of the gas argon, which does not react readily with other elements, would place it in the same group as the chemically very active solids lithium and sodium. In 1913 British physicist Henry Moseley confirmed earlier suggestions that an element's chemical properties are only roughly related to

its atomic weight (now known to be roughly equal to the number of protons plus neutrons in the nucleus). What really matters is the element's atomic number--the number of electrons its atom carries, which Moseley could measure with X-rays. Ever since, elements have been arranged on the periodic table according to their atomic numbers. The structure of the table reflects the particular arrangement of the electrons in each type of atom. Only with the development of quantum mechanics in the 1920s did scientists work out how the electrons arrange themselves to give the element its properties.

[On learning about the table] “For the first time I saw a medley of haphazard facts fall into line and order. All the jumbles and recipes and hotchpotch of the inorganic chemistry of my boyhood seemed to fit themselves into the scheme before my eyes — as though one were standing beside a jungle and it suddenly transformed itself into a Dutch garden.”

— *C.P. Snow*