Historical Evolution of Periodic Classification of Elements

- 1829, Johann Wolfgang Dobereiner put forth this TRIAD of elements.
- Stanislao Cannizzaro, 1860s, refined atomic mass determination by applying Avogadro's law and determining vapor density. O-16 was used as standard for defining relative atomic mass
- 1960, C-12 was used as standard (cu/u/Da)

- Why National Periodic Table Day: 7th February ?
- Because on 7th February, 1863, John Newland put forth the initial periodic Table with Law of Octaves

Antoine Lavoisier's classification of 33 elements into four element groups

Acid-making Elements	Gas-like Elements	Metallic Elements	Earthy Elements
Sulphur	Light	Antimony	Lime (calcium oxide)
Phosphorus	Caloric (heat)	Arsenic	Magnesia (magnesium oxide)
Charcoal (carbon)	Oxygen	Bismuth	Barytes (barium sulphate)
	Azote (Nitrogen)	Cobalt	Argilla (aluminium oxide)
	Hydrogen	Copper	Silex (silicon dioxide)
	Muriatic Radical	Gold	
	Fluoric Radical	Iron	
	Biracic Radical	Lead	
		Manganese	
		Mercury	
		Molybdena	
		Nickel	
		Platina	
		Silver	
		Tin	
		Tungstein	
		Zinc	

- Robert Boyle in 1680 discovered Phosphorus from residue of human urine distillation(cold fire).
- Lovoisier's Classification in 1789(*Elementary Treatise of Chemistry*) put forth his table containing 33 elements including light and caloric(heat) considered as elements.
- Dalton(1808-1810), Thomas Thomson, Prout and Berzelius started to determine the atomic masses of elements taking H as 1.

Dobereiner's Triad:1817

Element	Atomic Mass	Eement	Atomic Mass	Element	Atomic Mass	Element	Atomic Mass
Li	6.9	Ca	40.1	Cl	35.5	S	32
Na	23.0	Sr	87.4	Br	79.9	Se	79
K	39.1	Ba	137.3	I	126.9	Te	128

Triad Law: The g atomic mass of the middle element of each triad was approximately the average of the g atomic masses of the first and third elements in the triad.

23.0(Na) $= \frac{6.9(Li)+39.1(K)}{2}$; 87.4(Sr) $\approx \frac{40.1(Ca)+1 \quad .3(Ba)}{2}$=88.7

79.9(Br)=$\approx \frac{35.5(Cl)+126.9(I)}{2}$=81.2

Newland's Octave: 1866

Sa(Do)	H	F	Cl	Co, Ni	Br	Pd	I	Pt, Ir
Re(Re)	Li	Na	K	Cu	Rb	Ag	Cs	Os
Ga(Mi)	G(Be)	Mg	Ca	Zn	Sr	Cd	Ba, V	Hg
Ma(Fa)	Bo(B)	Al	Cr	Y	Ce, La	U	Ta	Tl
Pa(So)	C	Si	Ti	In	Zr	Sn	W	Pb
Dha(La)	N	P	Mn	As	Di, Mo	Sb	Nb	Au
Ni(Ti)	O	S	Fe	Se	Ro, Ru	Te	Au	Th

Di: Didymium(found to be a mixture of two elements Praseodymium(Pr) and Neodymium(Nd), but considered as one element during Newland's period
Ro: Later named as Rh(Rhodium)
G: *Glucinium*(named as Beryllium in 1957)

John Newlands

- Born November 26, 1837 in London, from a Scottish father and Italian mother England and died on July 29, 1898 in London (Lived for 61 years). He studied in Royal College of Chemistry (Imperial College London). Died during a surgery at home when he was 61. He used the *musical analogy of Pythagoras* in his chemical theory.

No.	No.	No.	No.	No.	No.	No.	No.
H 1	F 8	Cl 15	Co & Ni 22	Br 29	Pd 36	I 42	Pt & Ir 50
Li 2	Na 9	K 16	Cu 23	Rb 30	Ag 37	Cs 44	Tl 51
G 3	Mg 10	Ca 17	Zn 25	Sr 31	Bd [sic-Cd] 38	Ba & V 45	Pb 54
Bo 4	Al 11	Cr 19	Y 24	Ce & La 33	U 40	Ta 46	Th 56
C 5	Si 12	Ti 18	In 26	Zr 32	Sn 39	W 47	Hg 52
N 6	P 13	Mn 20	As 27	Di & Mo 34	Sb 41	Nb 48	Bi 55
O 7	S 14	Fe 21	Se 28	Ro & Ru 35	Te 43	Au 49	Os 51

https://web.lemoyne.edu/giunta/newlands.html

Mendeleev's Periodic Table in 1969

- Put forth on 6th March 1969 on the basis of increasing atomic masses. But in 1871, his Period Law and Periodic Table Table got wide reconition.
- 66 elements: Playing like a CARD GAME(Chemical Solitaire-Card game in train journeys) Arranged according the formula of their oxides and hydrides(valencies).
- Made three switches : (Co & Ni), (K, Ar), (I, Te)
- Father of Periodic Table.
- Similar elements were put in columns called GROUPS and horizontal rows were called Period in which change in properties occurred to produce dissimilar elements.
- There were 8 groups and 12 periods.

- **Law of Octaves:** Every eighth element was found to be similar to the first element, just like musical octave (Sa Re Ga Ma Pa Dha Ni Sa) or in the C-Major scale C-D-E-F-G-A-B-[C]
- This gave the concept of Periodic Law propounded by Mendeleev in terms of atomic masses of elements.
- Noble Gases not Discovered.
- Only 62 elements arranged.
- Elements having similar properties were then put in rows and having different properties were put in columns, which was opposite to Mendeleev's Table and the Long form.
- He was first to arrange elements in their relative atomic masses.
- Drawback: No room for new elements and dissimilar elements were put to the same family.

- **Mendeleev's Periodic Law:** Properties of elements are periodic functions of their atomic masses.
- In 1904, noble gases were discovered, as a result of which a new 9th group was appended to the PT.
- Empty Spaces and Prediction of New elements:
- Eka Boron: Scandium(III)-1879; Eka Aluminium: Gallium(III)-1875
- Eka Silicon : Germanium(IV)-1886
- Eka-Tellurium : Polonium(VI), Eka Cs: Francium; Eka Mn : Tc Technetium
- Eka Xe: Radon; Dvi-Mn : Re

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Period 1	H = 1							
Period 2	Li = 7	Be = 9.1	B = 11	C = 12	N = 14	O = 16	F = 19	
Period 3	Na = 23	Mg = 24.4	Al = 27	Si = 28	P = 31	S = 32	Cl = 35.5	
Period 4	K = 39.1	Ca = 40	? = 44	Ti = 48.1	V = 51.2	Cr = 52.3	Mn = 55	Fe = 56, Ni = 58.5, Co = 59.1, Cu = 63.3
Period 5	(Cu) = 63.3	Zn = 65.4	? = 68	? = 72	As = 75	Se = 79	Br = 80	
Period 6	Rb = 85.4	Sr = 87.5	Y = 89	Zr = 90.7	Nb = 94.2	Mo = 95.9	? = 100	Rh = 103, Ru = 103.8, Pd = 108, Ag = 107.9
Period 7	(Ag) = 107.9	Cd = 112	In = 113.7	Sn = 118	Sb = 120.3	Te = 125.2	I = 126.9	
Period 8	Cs = 132.9	Ba = 137	La = 138.5	Ce = 141.5	Di = 145			
Period 9								
Period 10			Yb = 173.2		Ta = 182.8	W = 184		Ir = 193.1, Pt = 194.8, Os = 200, Au = 196.7
Period 11	(Au) = 196.7	Hg = 200.4	Tl = 204.1	Pb = 206.9	Bi = 208			
Period 12				Th = 233.4		U = 239		

Lothar Mayer Classification

- German Chemist (19th August 2830 – 11th April 1895)
- 1864, he published his first table containing 28 elements with six families according to valencies.
- In 1970, he published his second table similar to Mendeleev's table.

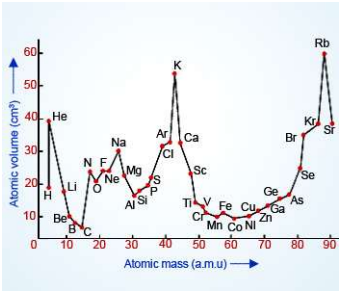
Group	I	II	III	IV	V	VI	VII	VIII
Oxide	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7	RO_4
Hydride	RH	RH_2	RH_3	RH_4	RH_3	RH_2	RH	
Periods	A B	A B	A B	A B	A B	A B	A B	
1	H 1.008							
2	Li 6.93	Be 9.01	B 10.81	C 12.01	N 14.00	O 15.99	F 18.99	
3	Na 22.99	Mg 24.31	Al 26.98	Si 28.09	P 30.97	S 32.06	Cl 35.45	
4 1st Series	K 39.10	Ca 40.08	— 44	Ti 47.90	V 50.94	Cr 52.10	Mn 54.9	Fe 55.85 Co 58.93 Ni 58.71
2nd Series	Cu 63.5	Zn 65.4	— 68	— 72	As 74.9	Se 79.0	Br 79.9	
5 1st Series	Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.91	Mo 95.94	Tc 99.0	Ru 101.0 Rh 102.9 Pd 106.4
2nd Series	Ag 107.9	Cd 112.4	In 114.82	Sn 118.69	Sb 121.75	Te 127.60	I 126.9	
6 1st Series	Cs 132.9	Ba 137.3						
2nd Series	Au 196.97	Hg 200.59						

Lothar Meyer's Periodic Table in 1864 (28 elements- six families

	Valence IV	Valence III	Valence II	Valence I	Valence I	Valence II	Mass difference
I row					Li	Be	~16
II row	C	N	O	F	Na	Mg	~16
III row	Si	P	S	Cl	K	Ca	~45
IV row		As	Se	Br	Rb	Sr	~45
V row	Sn	Sb	Te	I	Cs	Ba	~90
VI row	Pb	Bi			Tl		~90

Demerits

- Dissimilar elements put in same group (eg. Alkali metals with Cu,Ag, Au etc.). Later these were differentiated by using the concept of subgroups (A) and (B). For example, alkali metals-Gr.IA and Coinage metals(Cu, Ag, Au)-Gr IB etc.
- No regular increase in atomic masses, so no prediction as to how many elements can be accommodated or discovered in between two elements. (eg. Lanthanides and Actinides).
- No fixed place for H
- No places for Isotopes



Lothar Meyer Atomic Mass(amu)-Atomic Volume(cm^3) Graph

- Alkali metals such as Na, K, Rb occur on the peaks.
- F, Cl, Br occur at the rising or the ascending part of the curve
- Noble gases Ne, Ar, Kr occur just before alkali metals.
- Be, Mg, Ca fall just before the dips(minimum points) .
- H and He show exception.

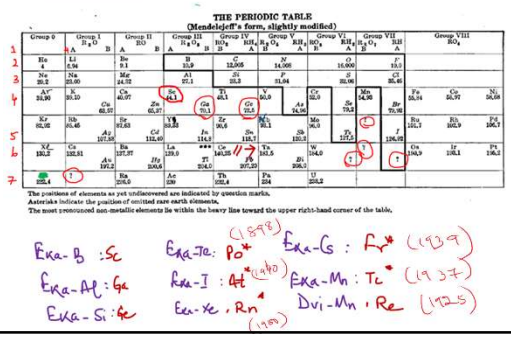
- 1897, JJ Thomson discovered electron. 1886, Eugen Goldstein, though discovered positive rays(canal rays) having different e/m ratio for different gases, only in 1917, Ernst Rutherford proved that hydrogen nucleus(PROTON) is present in all other nuclei.
- 1907, radioactivity was discovered in thorium and ISOTOPES were discovered.
- 1911, Ernst Rutherford discovered nucleus from his Gold foil experiment and gave the model of atom.
- 1913, Dutch Physicist Antonius van den Broek first proposed ATOMIC NUMBER(Nuclear Charge) is the basis of periodic classification.

Mendeleev's Modified Table in 1904

- Noble gases started to be discovered from 1894. First noble gas, Argon was discovered by Sir Willam Ramsay.
- A new group was added in the beginning for Noble gases, He, Ne, Ar, Kr, Xe.
- In the mean time Sc, Ga, Ge were discovered and added in the table.

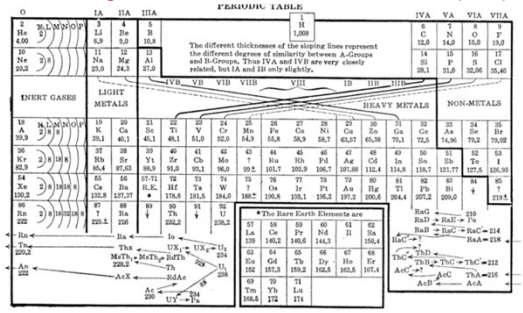
- 1913, Henry Moseley confirmed Broek's hypothesis that the properties of elements is due to its unique +ve charge i.e number of protons in the nucleus. Atomic Number is the number of protons present in the nucleus. Mosely from the x-ray spectra experiment on elements propounded the modern periodic Law.
- MODERN PERIODIC LAW. The properties of elements are periodic functions of their atomic numbers(Z). He predicted 4 new elements(43, 61, 72, 75)
- 1913, also Bohr gave this atomic model.
- Electronic Basis of Periodic Classification was found out.

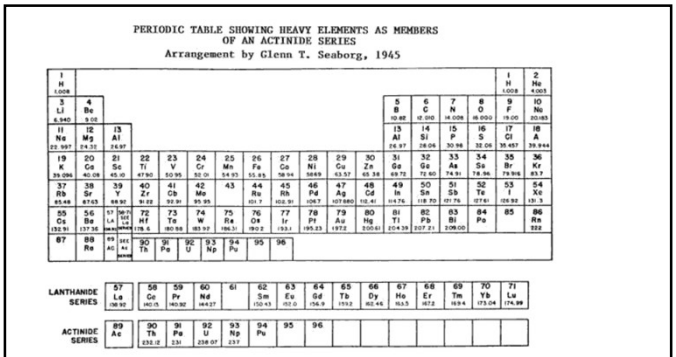
Mendelev's Modified Periodic Table: 1904



- Charles Bury, an English Chemist first used the word TRANSITION in 1921 for the transition series of elements in which the inner shell goes from 8 to 18 or from 18 to 32.
- H.G. Deming, USA in 1923 put forth the LONG FORM of Periodic Table, with (A) groups for Normal elements (Group Zero to Group VIIIA) with groups zero, IA, IIA in the left and IVA, VA, VIA and VIIA in the right. IIIA group also contained Sc, Yt, Rare Earths.
- The middle portion contain IIIA group and all (B) groups namely IVB, VB, VIB, VIIB, VIII(three series triads), IB, IIB, IIIB.
- Unfortunately, Sc, Y(t), Rare Earths, Some Actinides were in IIIA while IIIB contained Ga, In and Tl

H.G Deming's First LONG FORM with Transition Series (1925)

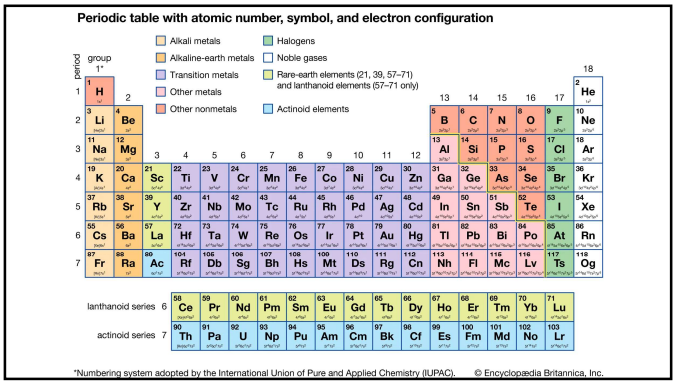




Moseley's Periodic Table Published in 1930

Group 0	I a	I b	II a	II b	III a	III b	IV a	IV b	V a	V b	VI a	VI b	VII a	VII b	VIII
	H 1														
He 2	Li 3		Be 4		B 5		C 6		N 7		O 8		F 9		
Ne 10	Na 11		Mg 12		Al 13		Si 14		P 15		S 16		Cl 17		
Ar 18	K 19	Cu 29	Ca 20	Zn 30	Sc 21	Ga 31	Ti 22	Ge 32	V 23	As 33	Cr 24	Se 34	Mn 25	Br 35	Fe 26, Co 27, Ni 28
Kr 36	Rb 37	Ag 47	Sr 38	Cd 48	Y 39	In 49	Zr 40	Sn 50	Nb 41	Sb 51	Mo 42	Te 52	–	I 53	Ru 44, Rh 45, Pd 46
Xe 54	Cs 55	Au 79	Ba 56	Hg 80	57–71*	Tl 81	Hf 72	Pb 82	Ta 73	Bi 83	W 74	Po 84	Re 75	–	Os 76, Ir 77, Pt 78
Rn 86	–		Ra 88		Ac 89		Th 90		Pa 91		U 92				

Gaps at 43, 61, 72 and 75.
43: Technetium(Radioactive, 1937), 61: Promethium(Radioactive, 1945)
72: Hafnium(stable, 1923), 75: Rhenium(Stable, 1925)



- Glenn T. Seaborg, University of Berkeley, CA, in 1945, restructured the periodic Table by placing the Actinide Series below the Lanthanide Series. He was instrumental in the discovery of many synthetic elements post WWII.
- In 1940, Neptunium and Plutonium were the first transuranic elements discovered.
- Superheavy elements in a transactinide series from 104 – 121 were synthesized one after the other.

Attemts to discover Ununennium(119) & Unbinilium(120)

- Hypothetical : Eka-francium
- Experiments started since 2018 I RIKEN, Japan and also JINR, Dubna, Russia lately

$$^{254}_{99}Es + ^{48}_{20}Ca \rightarrow ^{302}_{119}Uue^* \rightarrow \text{no atoms}$$

$$^{249}_{97}Bk + ^{50}_{22}Ti \rightarrow ^{299}_{119}Uue^* \rightarrow \text{no atoms}$$

$$^{249}_{98}Cf + ^{50}_{22}Ti \rightarrow ^{299}_{120}Ubn^* \rightarrow \text{no atoms}$$

Life History of Dimitri Mendeleev, Father of Periodic Table

- Born on 8th February 1834 in Siberia to Ivan Mendeleev and Maria Mendeleeva. His father was school teacher of arts, politics and philosophy. Mother Maria was running the family glass factory.
- Dimitri was youngest of 17 siblings of whom 14 stayed alive.
- Studied Main Pedagogical Institute in St. Petersburg, Moscow.
- 1861, he published a text book named 'Organic chemistry".
- He married to Feozva Nikitichna Leshcheva on 17th April 1862.
- He became Professor at St. Petersburg Tech Institute and State university in 1864 and 1865 respectively. Got DSc in 1865.

- In 1876 (when he as 42) he fell in love with Anna Ivanova Popova and proposed her and threatened to commit suicide if she refused.
- He got divorce from Leshcheva and married Popova on April 2, 1882.
- He was technically a bigamist, much against orthodox law.
- Got umpteen number of awards and prizes.
- Nobel prize in 1906.
- Died in 1907(at 72) from influenza. His last words to doctor
- "Doctor, you have science, I have faith,"

Henry Moseley

- Died in battle as a WW1 volunteer at Gallipoli, Turkey on August 10 1915 at the age of 27 !!!!!
- He wrote, "We have here proof that there is in the atom a fundamental quantity, which increases by regular steps as one passes from one element to the next. This quantity can only be the charge on the central positive nucleus, of the existence of which we already have definite proof" (1913)