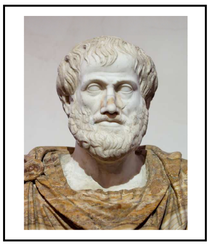
Historical Landmarks in the Development of the Periodic Table

S. Vasudevan
CSIR-Central Electrochemical Research Institute, Karaikudi-630003
E-maul: vasudevan65@gamil.com

The development of the periodic table of the elements is one of the most significant achievements in science with broad implications in chemistry, physics, astronomy and other natural sciences. So the United Nations (UN) general assembly (72nd session) declared 2019 as the International Year of the Periodic Table of chemical elements (ITPT 2019). Accidentally the ITPT will coincide with the 150th anniversary of the discovery of the periodic system by Dmitry Mendeleev, a Russian chemist who in 1869 wrote out the known elements (of which there were 63 elements at the time) on cards and then arranged them according to their chemical and physical properties in columns and rows. As a result of the development, the periodic table stares from the wall of just about every chemistry labs of schools and colleges. The periodic table was not actually started with Dmitry Mendeleev. Many scientists/chemists had attempted with arranging the elements.

1. Aristotle's periodic table



Going back to ancient times (400 BC), we can see the roots of our understanding of the elements that make up the periodic table. In ancient Greece, Aristotle and Plato thought that everything on the planet came from four root sources. They were fire, water, air and earth (Figure 1). In ancient times, elements like gold and silver were readily accessible; however, the elements that Aristotle chose were Earth, Water, Fire, and Air. Therefore, we can say that the ancient Greeks did understand the nature of elements and what they were in a basic way. But they didn't do much to advance our understanding of matter; that is something that would come later.

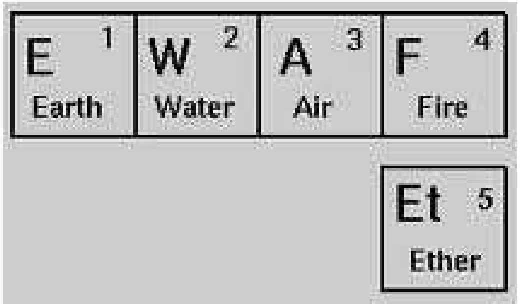
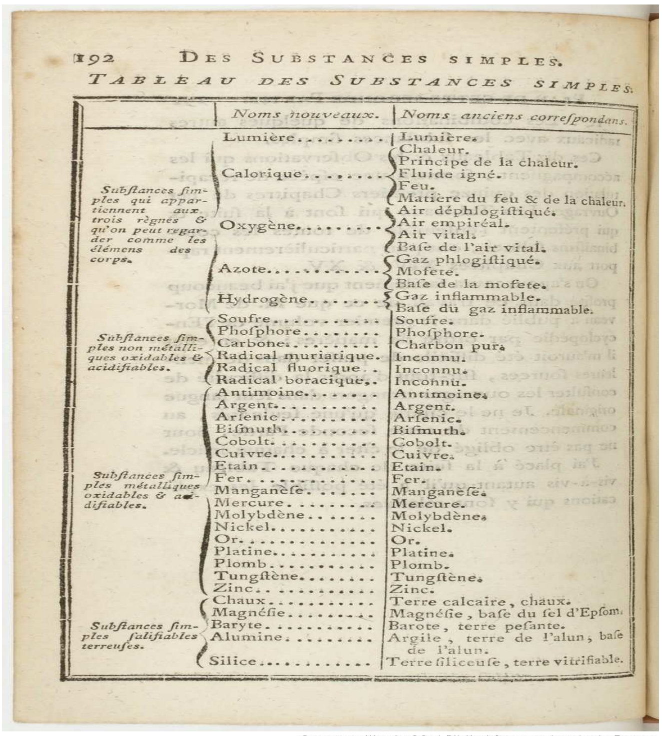


Figure 1. Aristotle's periodic table

2. Antoine Lavoisier Periodic Table (1770 - 1789)

Antoine Lavoisier (1789) wrote the first list of 33 elements. He classified them as metals and nonmetals, though we now know that some were compounds or mixtures.



192 DES SUBSTANCES SIMPLES.

TABLEAU DES SUBSTANCES SIMPLES.

	Noms nouveaux.	*Noms anciens correſpondans.*
Subſtances ſimples qui appartiennent aux trois règnes & qu'on peut regarder comme les élémens des corps.	Lumière	Lumière.
	Calorique	Chaleur. Principe de la chaleur. Fluide igné. Feu. Matière du feu & de la chaleur.
	Oxygène	Air déphlogiſtiqué. Air empiréal. Air vital. Baſe de l'air vital.
	Azote	Gaz phlogiſtiqué. Mofete. Baſe de la mofete.
	Hydrogène	Gaz inflammable. Baſe du gaz inflammable.
Subſtances ſimples non métalliques oxidables & acidifiables.	Soufre	Soufre.
	Phoſphore	Phoſphore.
	Carbone	Charbon pur.
	Radical muriatique.	Inconnu.
	Radical fluorique	Inconnu.
	Radical boracique.	Inconnu.
Subſtances ſimples métalliques oxidables & acidifiables.	Antimoine	Antimoine.
	Argent	Argent.
	Arſenic	Arſenic.
	Biſmuth	Biſmuth.
	Cobolt	Cobolt.
	Cuivre	Cuivre.
	Etain	Etain.
	Fer	Fer.
	Manganeſe	Manganeſe.
	Mercure	Mercure.
	Molybdène	Molybdène.
	Nickel	Nickel.
	Or	Or.
	Platine	Platine.
	Plomb	Plomb.
	Tungſtène	Tungſtène.
	Zinc	Zinc.
Subſtances ſimples ſalifiables terreuſes.	Chaux	Terre calcaire, chaux.
	Magnéſie	Magnéſie, baſe du ſel d'Epſom.
	Baryte	Barote, terre peſante.
	Alumine	Argile, terre de l'alun, baſe de l'alun.
	Silice	Terre ſiliceuſe, terre vitrifiable.

Source gallica.bnf.fr / Bibliothèque nationale de France

Figure 2. Traité Élémentaire de Chimie, Cuchet, Paris, 1789, p. 192

3. John Dalton's Periodic Table (1808 – 36)

In 1803, the English school teacher and part-time scientist, John Dalton published his first list of elements when he printed his atomic theory and his early gas law work. His original list showed only five elements: hydrogen, oxygen, azote (nitrogen), carbon and sulphur along with their atomic weight (Figure 3).

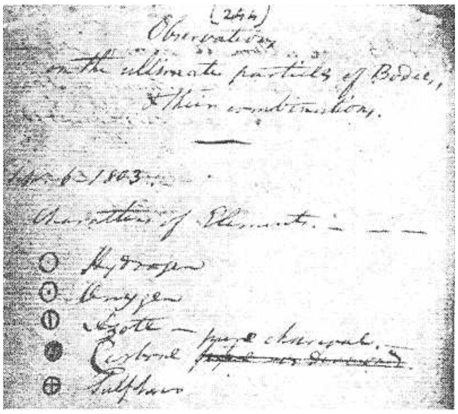


Figure 3. Dalton's first list of elements published in 1803 contained only five elements.

Latter Dalton attempted to create a system to symbolize the elements, making them easier to write them down quickly. So Dalton's first volume of his second major work was published in 1808, his newest work included more elements and even compounds. (Figure 4)

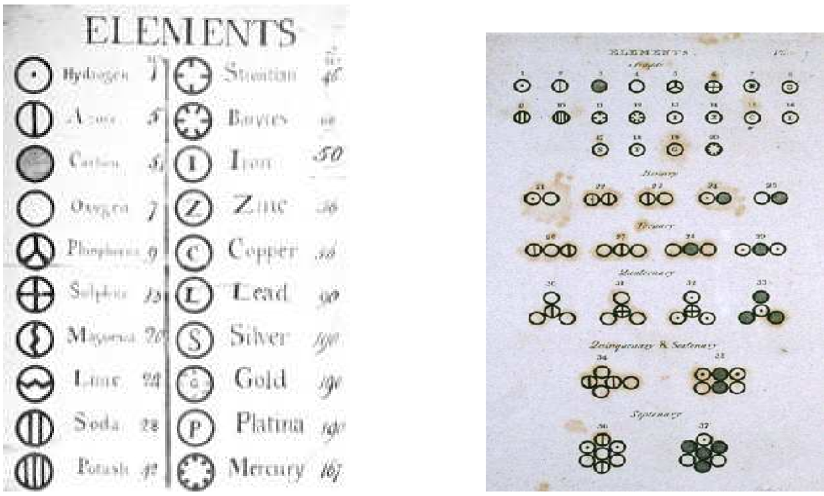


Figure 4 Dalton's second list of elements (a) with their atomic masses and (b) some combinations of elements.

When the second volume of his work came out in 1827, the list of elements had grown to 36 (Figure 5). His symbols may look strange since they were not easy to remember and have not been used since the work was published.

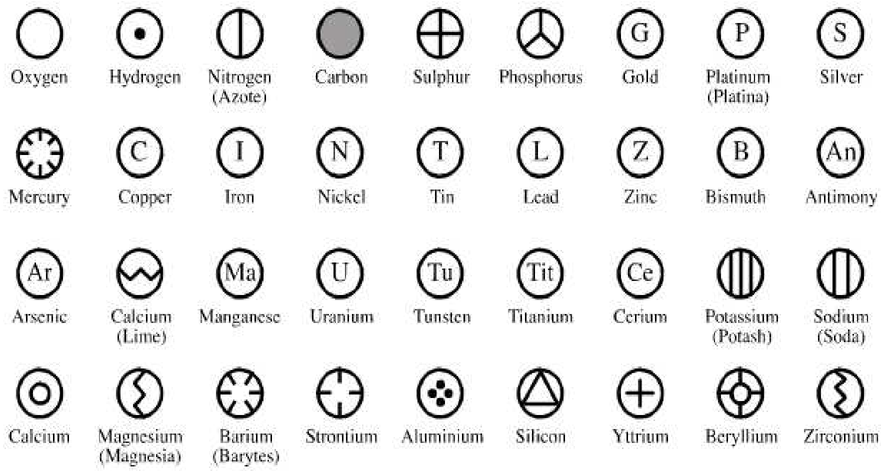


Figure 5 Second volume of his work with the list of 36 elements.

However, Dalton's symbols did have some benefits: each symbol represented one atom and the formula of a compound was made up of the symbols of its elements, it showed how many of these atoms were present in the molecule.

4. Jöns Berzelius Periodic Table (1779–1848)

A few years later Dalton's system was superseded with the chemical symbols and formulae by Jöns Berzelius, which are still used today. Berzelius was a Swedish chemist. In 1828 he compiled a table of relative atomic weights, where oxygen was set to 100, and which included all of the elements known at the time. Of significance for the periodic table is that he invented the modern system of chemical notation and established the basic symbols for the elements as used today. In this system elements are given symbols, and compounds represented by combining element symbols and numbers representing proportions. Students working in Berzelius laboratory are credited with discovering lithium, and vanadium. Other elements attributed to Berzelius are silicon, selenium, thorium, and cerium. Together with John Dalton and Antoine Lavoisier he is considered a father of modern chemistry.

Element	Berz.	present
Aluminium	Al	
Argentum (Silver)	Ag	
Arsenic	As	
Aurum (Gold)	Au	
Barium	Ba	
Bismuth	Bi	
Boron	B	
Calcium	Ca	
Carbon	C	
Cerium	Ce	
Chromium	Ch	Cr
Cobalt	Co	
Columbium	Cl (Cb)	Nb
Cuprum (Copper)	Cu	
Ferrum (Iron)	Fe	
Fluoric Radicle	F	

Element	Berz.	present
Glucinum	Gl	Be
Hydrargyrum (Mercury)	Hg (Hy)	Hg
Hydrogenium	H	
Iridium	I	Ir
Magnesium	Ms	Mg
Manganese	Ma (Mn)	Mn
Molybdenum	Mo	
Muriatic Radicle (Chlorine)	M	Cl
Nickel	Ni	
Nitric Radicle	N	
Osmium	Os	
Oxygenium	O	
Palladium	Pa	Pd
Phosphorus	P	
Platinum	Pt	
Plumbum (Lead)	Pb (P)	Pb

Element	Berz.	present
Potassium	Po	K
Rhodium	Rh (R)	Rh
Silicium	Si	
Sodium	So	Na
Stibium (Antimony)*	Sb (St)	Sb
Strontium	Sr	
Sulphur	S	
Tellurium	Te	
Tin	Sn (St)	Sn
Titanium	Ti	
Tungsten	Tn (W)	W
Uranium	U	
Yttrium	Y	
Zinc	Zn	
Zirconium	Zr	

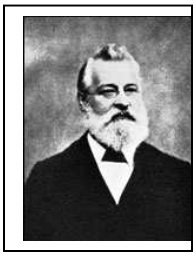
5. Johann Döbereiner's Periodic Table (1780–1849)

Döbereiner was a German chemist whose examinations of the correspondence of certain elements prompted the development of the Periodic Table. Because he was a coachman's son, he had a small opportunity, for formal schooling. However, he was apprenticed to an apothecary, read widely, and attended science lectures. Eventually, he was able to attend the University of Jena, where he became assistant professor and later become the supervisor of science institutions. Although he had numerous scientific achievements, he is best known for his contributions to the creation of the Periodic Table. Between 1817 and 1829, he began to group elements with similar properties into groups of three, or triads. This accomplishment initiated when he realized that the atomic weight of Strontium was halfway between the weight of calcium and barium. He also noted that the elements possessed similar chemical properties. Thus, by 1829 he had discovered the halogen triad composed of chlorine, bromine and iodine, and the alkali metal triad of lithium, sodium and potassium. Furthermore, he suggested that nature encompassed triads of elements whereby the middle element has properties that were an average of the other two elements. However, the poor accuracy of measurements, such as atomic weight, hindered the classification of more elements.

Alkali formers	
Li	7
Na	23
K	39

Salt formers	
Cl	35.5
Br	80
I	127

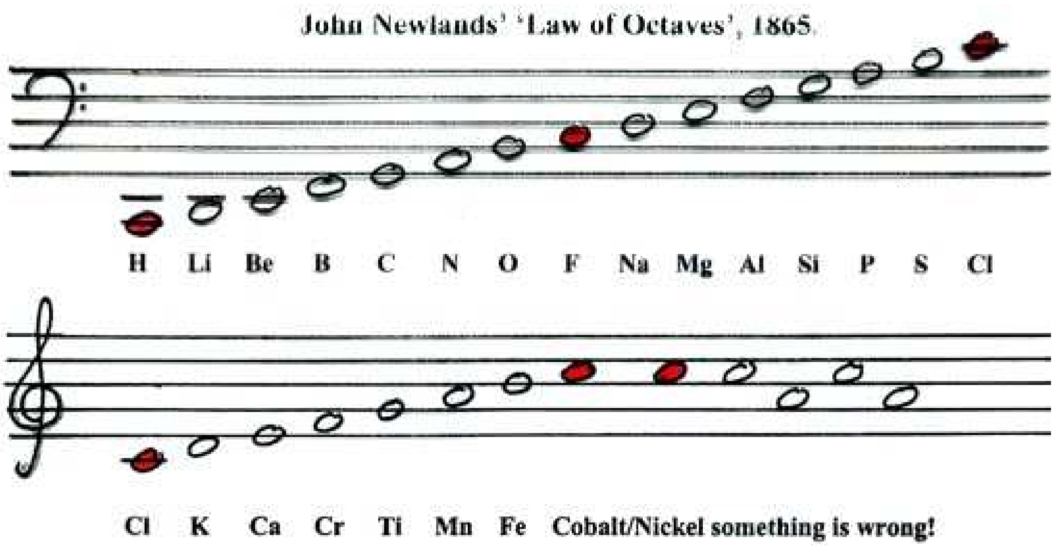
6. Newlands Periodic Table (1837–1898)



Newlands continuing the work of Döbereiner with triads and the work of Jean-Baptiste Dumas families of similar elements, he published in 1865 his 'Law of Octaves', an innovative concept proposing the periodicity of the chemical elements arranged in order of atomic weight. He pointed out that every eighth element in this grouping shared a resemblance and suggested an analogy with the intervals of the musical scale. John Newlands put forward his law of octaves in 1864 in which he arranged all the elements known at the time into a table in order of relative atomic mass. When he did this, he found that each element was similar to the element eight places further on. However, this law had some setbacks. For example, he placed iron, a metal, in the same group as oxygen and sulfur, two nonmetals. Additionally, this musical analogy was ridiculed. However, it was found to be profound after the work os Mendeleev and Mayer were published. Newlands was also the first chemists to assign atomic numbers to the element.

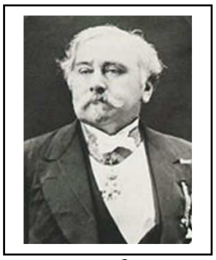
Newlands' Octaves (his 'Periodic Table' of 1866)						
H	Li	Ga	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe
Co, Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce, La	Zr	Di, Mo	Ro, Ru
Pd	Ag	Cd	U	Sn	Sb	Te
I	Cs	Ba, V	Ta	W	Nb	Au
Pt, Ir	Tl	Pb	Th	Hg	Bi	Th

Newlands' Version of the Periodic Table

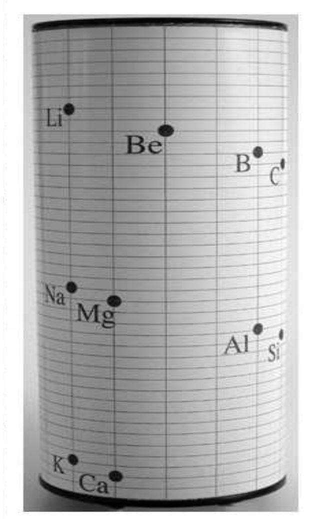


Newlands' "Law of Octaves"

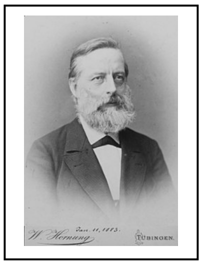
7. de Chancourtois Periodic Table



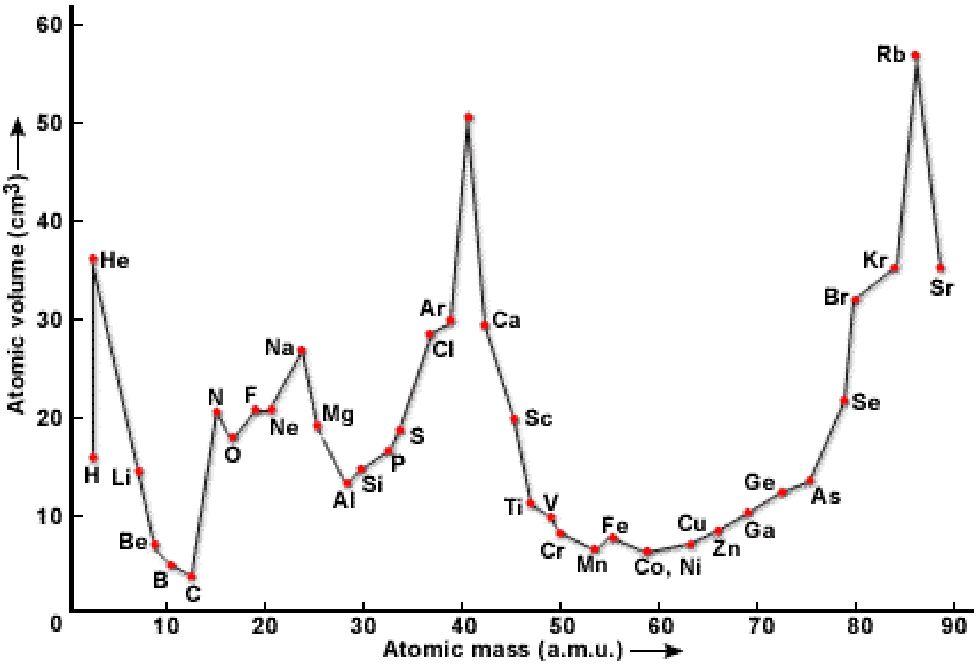
In 1862, before Newlands announced his Law of Octaves and Mendeleev described his Periodic System, de Chancourtois presented his idea on periodic table before the French Academy before the French Academy of Sciences. de Chancourtois called his idea "vis tellurique" or telluric spiral because the element tellurium came in the middle. It was also somewhat appropriate coming from a geologist as the element tellurium is named after the Earth. He plotted the atomic weights on the outside of a cylinder such that one complete turn corresponded to an atomic weight increase of 16. However, the concept was poorly presented and difficult to understand.



8. Lulius Lothar Meyer Periodic Table (1830-1895)

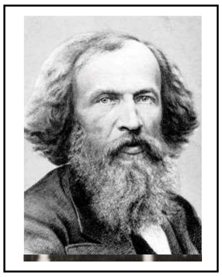


Meyer was contemporary with Mendeleev; he qualified in medicine at Zürich, Switzerland, and then studied and taught at various German universities. Thought his first interest was physiology he was primarily interested in chemistry. Meyer was examining the physical properties of the elements and noticed a periodicity in their molar volume. He independently developed a periodic table based on atomic masses. He found that if the atomic volumes of the elements were plotted against their atomic weight, a series of peaks were produced. The peaks were formed by the alkali metals Sodium, Potassium, Rubidium, and Cesium. Each fall and rise to a peak, corresponded to a period like the waves. In each period a number of physical properties other than atomic volume also fell and rose, such as valence and melting point. Meyer was the first scientist to introduce the concept of valence as a periodic property.



In 1864, Meyer published a preliminary list of 28 elements classified into 6 families by their valence. Then in 1868 he prepared an expanded version, and in 1870 published his list as a table that in many ways was similar to Mendeleev's.

9.0 Mendeleev's Periodic Table (1834–1907)



Dmitri Mendeleev, was a Siberian-born Russian chemist. Mendeleev was investigating the variation in the chemical properties of the elements and noticed their periodic variation. When his family's glass factory was destroyed by fire, Mendeleev moved to St. Petersburg, Russia, to study science. He became ill and was not expected to recover, but he finished his PhD with the help of his professors and fellow students. He is the best known for his development of the first version of the Periodic Table and utilized it to anticipate the elements yet to be discovered. Legend says that on the night of 17, February 1869, Mendeleev went to bed frustrated because he could not decipher the greatest puzzle of all the Periodic Table. That night, he dreamed of a table where all the elements fell into the correct place. His first Periodic Table arranged the elements in order of increasing atomic mass and grouped them by similarity of properties. When a gap existed in the table, Mendeleev predicted that a new element would one day be discovered and assumed its properties. He arranged the 63 known elements into a Periodic Table and recorded it in his book, Principles of Chemistry, in 1869. Furthermore, Mendeleev revealed that the properties of certain elements were inaccurate. Because the noble gases had not yet been discovered, they were not included in this table.

			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?		

10. Henry Moseley's Periodic Table (1887 – 1915)

Henry Moseley was an English chemist who discovered the application of the X-ray spectra to study atomic structure. He found that the wavelength of an X-ray depended on the nuclear charge of an atom. In 1913, he photographed the X-ray spectrum of 10 elements that held successive places in the Periodic Table. Moseley's discoveries produced a more accurate positioning of the elements in the Periodic Table – the use of atomic number as the organizing principal for the periods. Argon, for example, although having an atomic mass greater than that of potassium, was placed before potassium in the periodic table. While analyzing the frequencies of the emitted x-rays, Moseley noticed that the atomic number of argon is 18, whereas that of potassium is 19, which indicated that they were indeed placed correctly. According to Mendeleev the elements are arranged based on atomic mass, but this was created some setbacks. For example, Iodine has a lower atomic mass then tellurium. Based on the Mendeleev's Periodic Table, Iodine should come before Tellurium. So, in order to place Iodine in the same group as other elements with similar properties, Mendeleev had to place it after Tellurium, and thus broke his own rules. Moseley's concept (based on the atomic number) solved the problem faced by Mendeleev's table. Following is the Moseley's Periodic Table.

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

missing elements ignore this for now

Moseley's Periodic Table

Moseley left his research work at the University of Oxford to join the British army as a telecommunications officer during World War I. He was killed during the Battle of Gallipoli in Turkey.

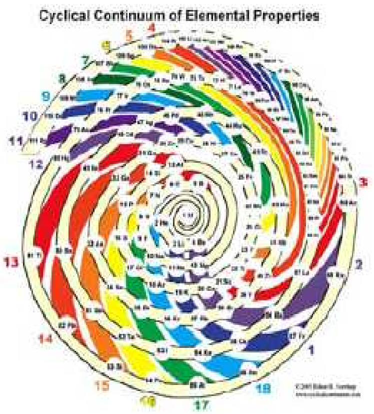
Summary

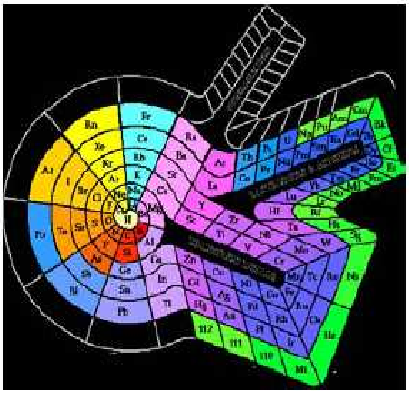
- Before 1800 (34 elements): discoveries during and before the age of enlightenment.
- 1800-1849 (24 elements): impulse from Scientific Revolution and Atomic theory and Industrial Revolution.
- 1850-1899 (26 elements): the age of classifying elements; application of spectrum analysis techniques

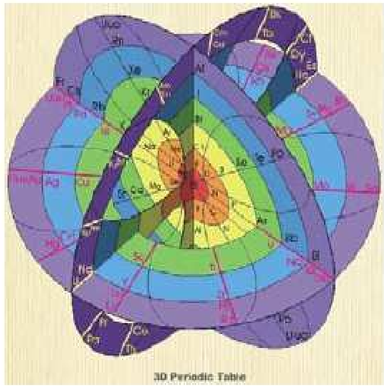
- 1900-1949 (13 elements): development of old quantum theory and quantum mechanics.
- 1950-1999 (16 elements): "post atomic bomb" era; synthesis of atomic numbers 98 and above
- 2000-present (5 elements): recent synthesis.

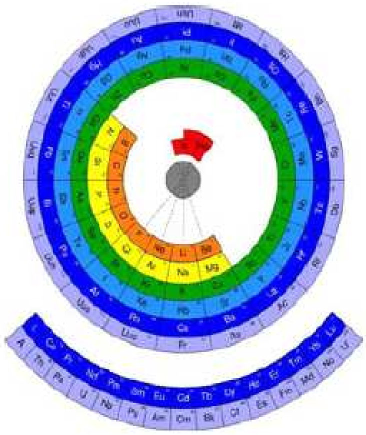
The elements in the periodic table are arranged according to their properties, and the periodic table serves as an aid in predicting chemical behavior. The periodic table arranges the elements according to their electron configurations, such that elements in the same column have the same valence electron configurations. Periodic variations in size and chemical properties are important factors in dictating the types of chemical reactions the elements undergo and the kinds of chemical compounds they form. The modern periodic table was based on empirical correlations of properties such as atomic mass; early models using limited data noted the existence of triads and octaves of elements with similar properties. The periodic table achieved its current form through the work of Dimitri Mendeleev and Julius Lothar Meyer, who both focused on the relationship between atomic mass and chemical properties. Meyer arranged the elements by their atomic volume, which today is equivalent to the molar volume, defined as molar mass divided by molar density. The correlation with the electronic structure of atoms was made when H. G. J. Moseley showed that the periodic arrangement of the elements was determined by atomic number, not atomic mass.

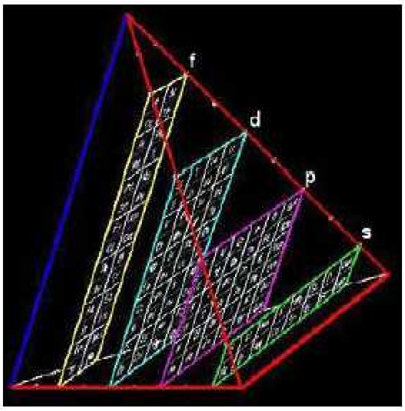
Some pictures for knowledge

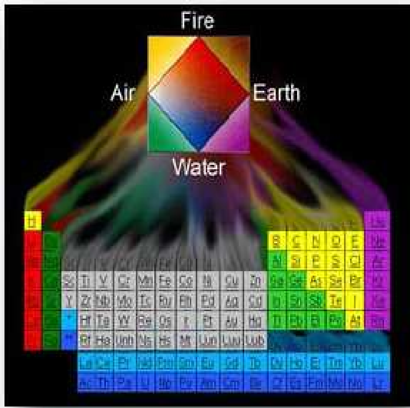




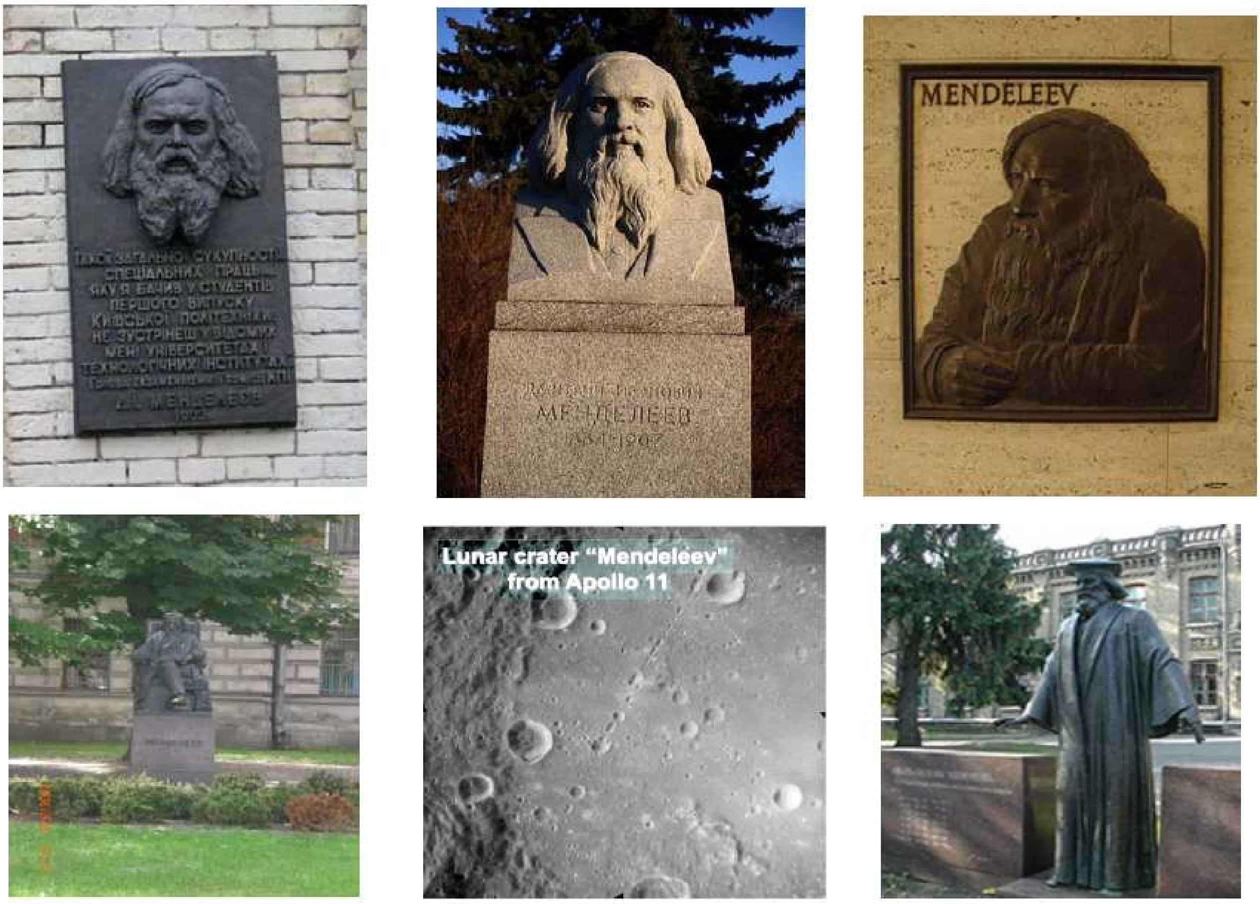








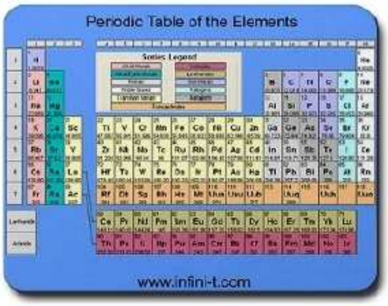
Different types of periodic arrangements

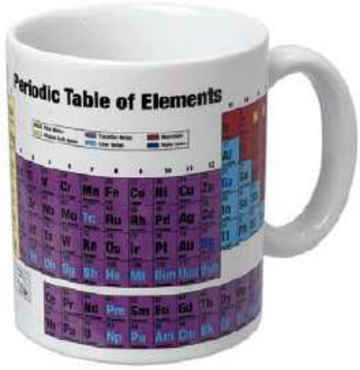


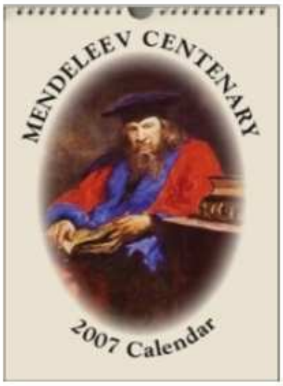
Some statues of Mendeleev

Commemorative stamps and first day covers of Mendeleev

Coins and Medallions

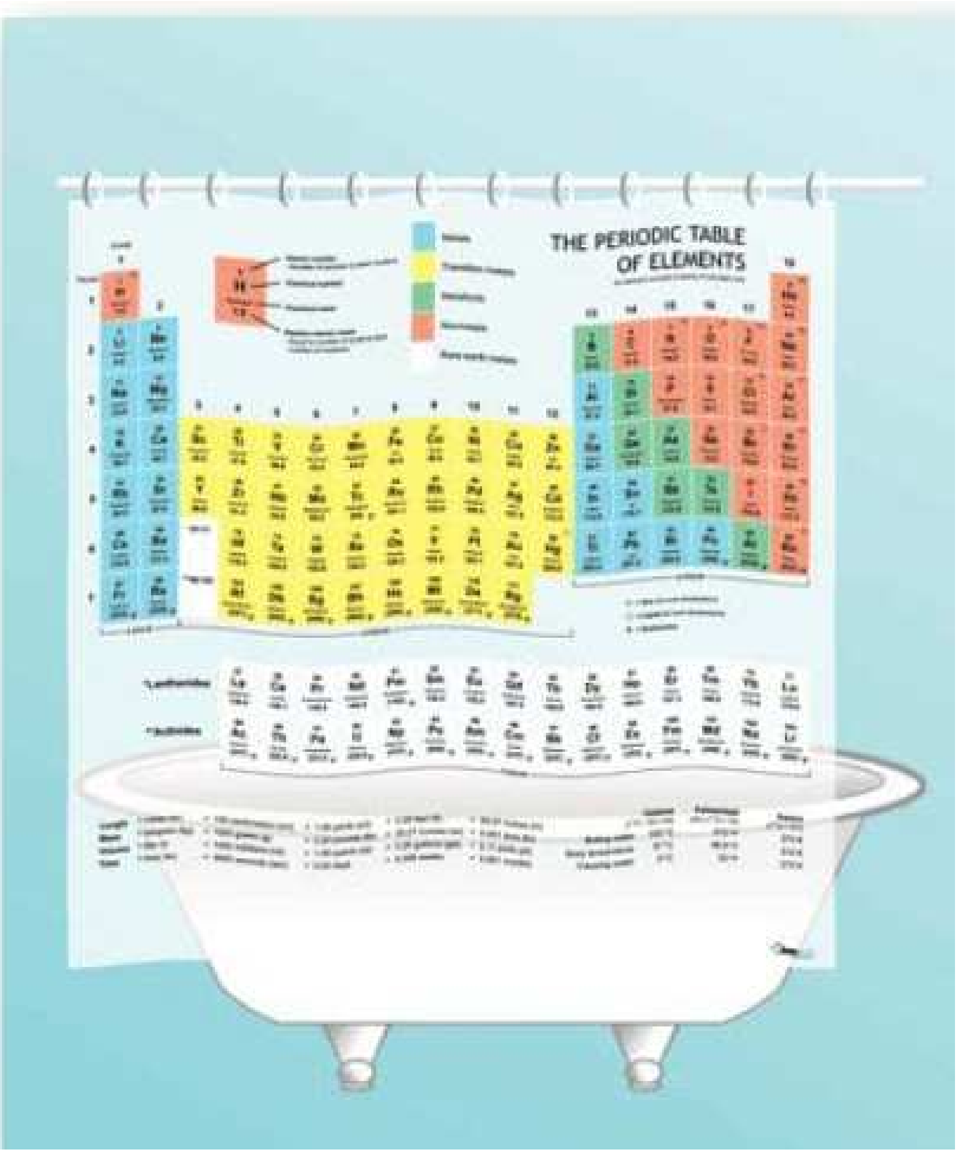






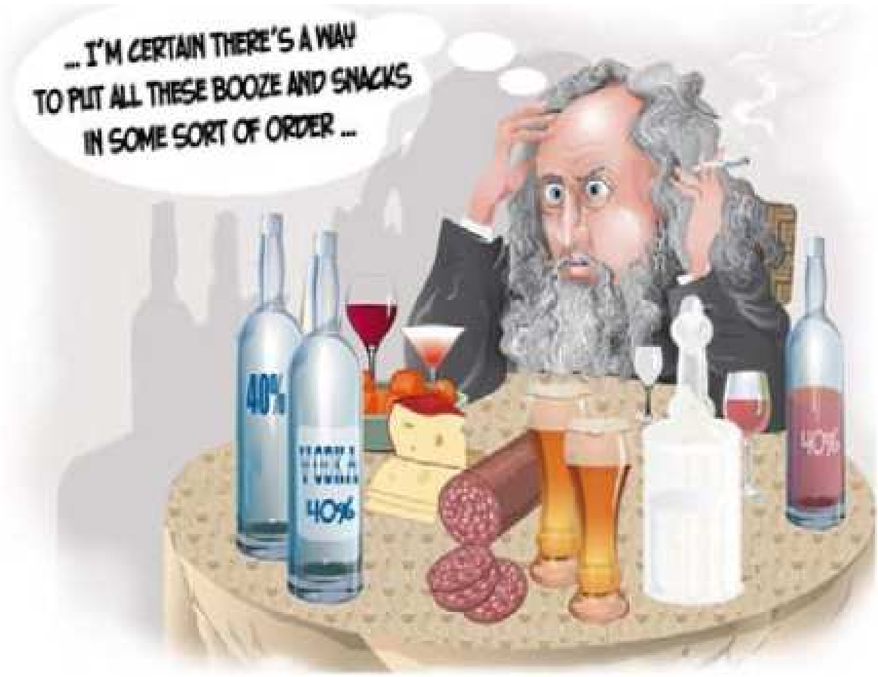
Periodic Paraphernalia

Periodic Table design at WebElements Shop

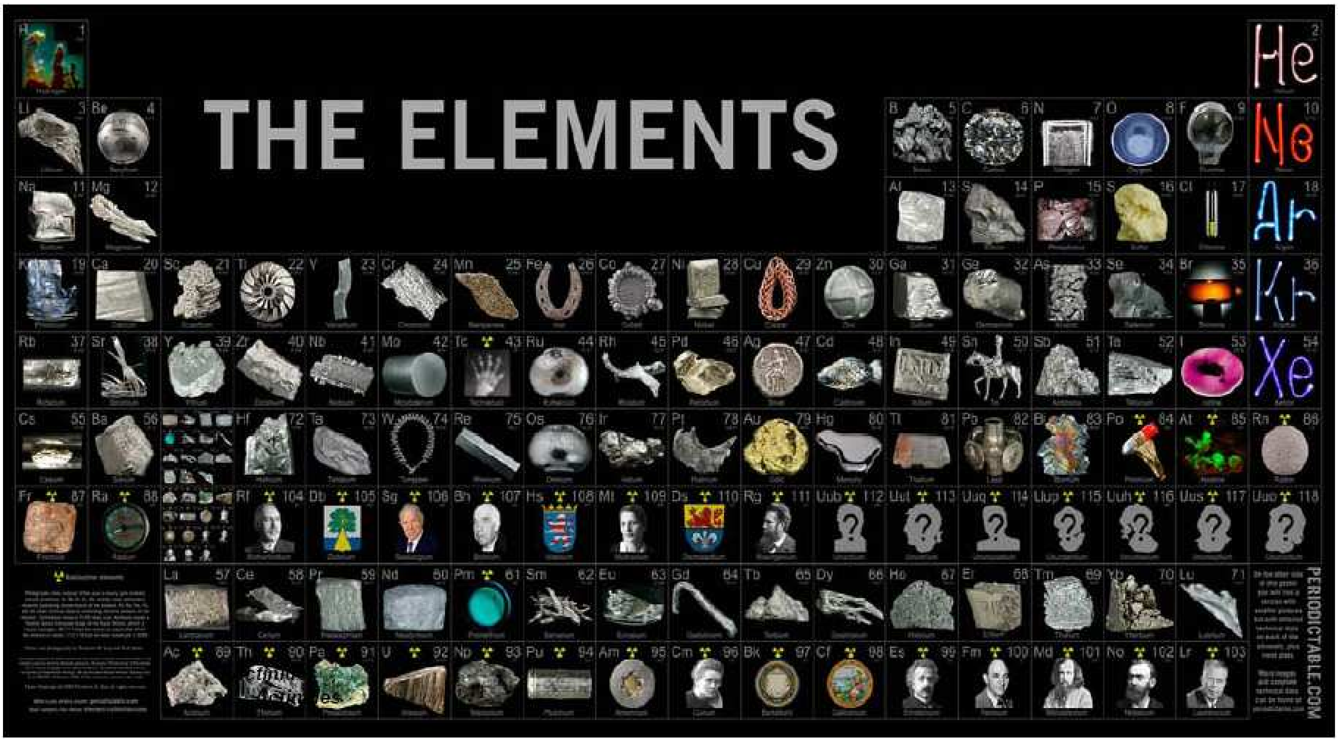


Periodic Table shower curtain

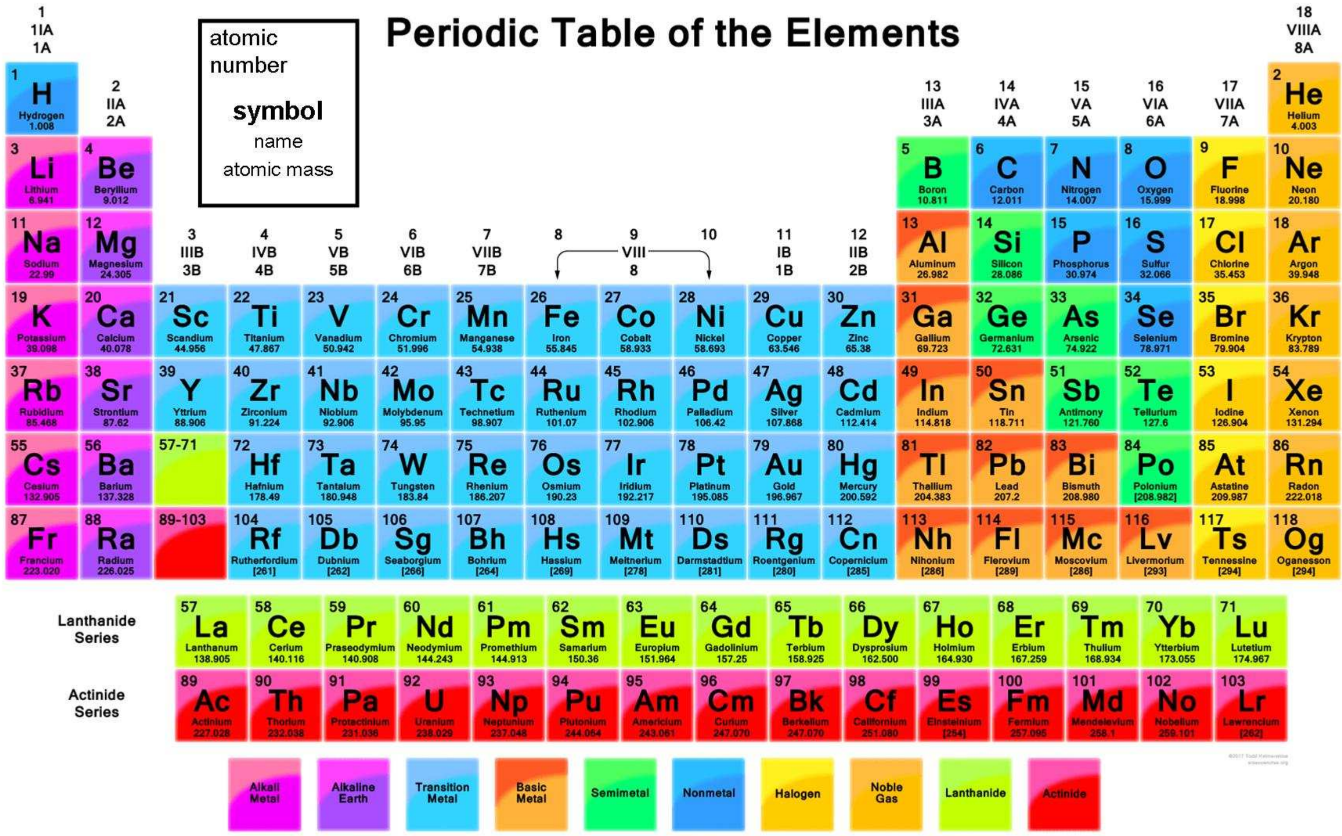
One day, maybe we will understand why Mendeleev's son always arranges his blocks the same way (A moment in the life of the Mendeleev family)



Periodic Table Humor



Fun Periodic Table (Periodic Table with some real elements)



Periodic Table now....

Bibliography

1. Scerri, E. R. (2006). The Periodic Table: Its Story and Its Significance; New York City, New York; Oxford University Press.

2. http://www.rsc.org/education/teachers/learnnet/periodictable/pre16/develop/mendeleev.htm

3. http://allperiodictables.com/ClientPages/AAEpages/aaeHistory.html

4.https://chem.libretexts.org/Ancillary_Materials/Exemplars_and_Case_Studies/ Exemplars/Culture/History_of_the_Periodic_Table

5.https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry__The_Central_Science_(Brown_et_al.)/07._Periodic_Properties_of_the_Elements/7.3%3A_Sizes_of_Atoms_and_Ions

6. http://elements.vanderkrogt.net/chemical_symbols.php

7. https://corrosion-doctors.org/Periodic/Periodic-de-Chancourtois.htm

8. https://corrosion-doctors.org/Periodic/Periodic-Newlands.htm

9. http://www.newworldencyclopedia.org/entry/History_of_the_periodic_table

10. Traité Élémentaire de Chimie, Cuchet, Paris, 1789, p. 192

11. Antoine Lavoisier (1743-1794) from Elements of Chemistry

12. From Alchemy to Chemistry: Five Hundred Years of Rare and Interesting Books

13. John Dalton (1766-1844): The Father of the Chemical Atomic Theory