Development of the Periodic Table

One of the most important scientific activities is the search for order. If a large number of observations or objects can be arranged into categories according to their common features, it becomes easier to describe them. Moreover, it may be possible to discover an underlying cause for a particular order. This in turn may lead to a significant scientific discovery. .

Elements with similar outer electron configurations behave alike in many ways. This fact helps us in grouping the elements according to the positions they now occupy in the periodic table. But this is not the way the original periodic table was constructed in the 19th century. The chemists of that time had only a vague idea of atoms and" molecules and did not know of the existence of protons and electrons.' Instead they constructed the periodic table using their knowledge of atomic masses. Accurate measurements of the atomic masses of many elements had already been made. Arranging elements according to their atomic masses in a periodic table seemed logical to those chemists, who felt that chemical behaviour should somehow be related to atomic mass.

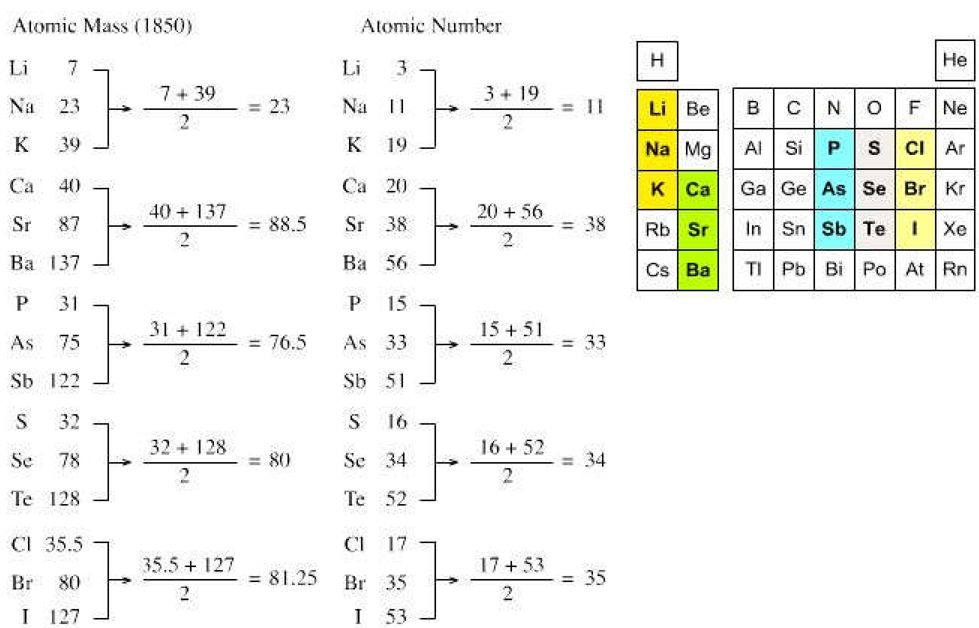

Fig 1. Dobereiner's Triad

Dobereiner's Triad

In 1829 Johann Dobereiner (1780-1849) observed that some of the known elements could be grouped' in three's (triads) according to similarities in their chemical and physical properties. In these triads the central member has an atomic weight that is roughly the average of other two as illustrated in Fig 1. Since Dobereiner's triads included only a few elements, this relationship was not considered a good classification. Other attempts to relate the properties of the elements to their atomic masses were not successful, partly because of the available values for atomic masses. Dobereiner's concept of triads, inspite of its limitations has provided the background to seek further information for the classification of elements.

	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	Os	51
G	3	Mg	10	Ca	17	Zn	24	Sr	31	Cd	38	Ba & V	45	Hg	52
Bo	4	Al	11	Cr	19	Y	25	Ce & La	33	U	40	Ta	46	Tl	53
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Pb	54
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	Th	56

Fig 2. Newlands octaves

Newlands Octaves

In 1864 the English chemist John Newlands noticed that when the known elements were arranged in order of atomic mass, every eight element had similar properties. Newlands referred to this peculiar relationship as the law of octaves. However this" law" turned out to be inadequate for elements beyond calcium.

Though ridiculed for leaving blank spaces for the yet undiscovered elements, he was the *1st* forerunner of the present periodic table, and was awarded the Davy Medal by the Royal Society (1887) in recognition of his contribution.

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=52	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	-	- - - -

Fig 3. Mendeleev's periodic table

Julius Lothar Meyer (1830-1895)

Table from *Annalen der Chemie, Supplementband* 7, 354 (1870).

Periodic table according to Lothar Meyer, 1870

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	B=11,0	Al=27,3		--		?In=113,4	Tl=202,7	
			--		--		--	
	C=11,97	Si=28		--		Sn=117,8		Pb=206,4
			Ti=48		Zr=89,7		--	
	N=14,01	P=30,9		As=74,9		Sb=122,1		Bi=207,5
			V=51,2		Nb=93,7		Ta=182,2	
	O=15,96	31,98		Se=78		Te=128?		--
			Cr=52,4		Mo=95,6		W=183,5	
--	F=19,1	Cl=35,38		Br=79,75		J=126,5		--
			Mn=54,8		Ru=103,5		Os=198,6 ?	
			Fe=55,9		Rh=104,1		Ir=196,7	
			Co=Ni=58,6		Pd=106,2		Pt=196,7	
Li=7,01	Na=22,99	K=39,04		Rb=85,2		Cs=132,7		--
			Cu=63,3		Ag=107,66		Au=196,2	
?Be=9.3	Mg=23,9	Ca=39,9		Sr=87,0		Ba=136,8		--
			Zn=64,9		Cd=111,6		Hg=199,8	

Fig 4. Lother Meyer's 's periodic table

Mendeleev's Periodic Table and Periodic Law

The major portion of the credit for the development of the periodic system must go to the Russian, Dimitrii Ivanovich Mendeleev, and the German Julius Lother Meyor. Both observed independently that properties of the elements can be represented' as periodic functions of their atomic weight. Mendeleev published the first account of his periodic system in 1869, a few months before the publication of the table by Meyer. Their work was recognized by the Royal Society in 1882 by the presentation of the Davy Medal to both.

Mendeleev arranged the known elements in order of their increasing atomic weights. He found that if elements are arranged in order of their increasing atomic weights, their properties vary in a regular manner, from one member to another in series.

He concluded that ***"physical and chemical properties of elements are periodic function of their atomic weights".*** This is known as Mendeleev's Periodic Law. Mendeleev's arrangement of the elements are shown in Fig 3.

Salient Features of Mendeleev's Table

The salient features of the Mendeleev's table of elements are:

(i) *The vertical columns are called Groups. These are numbered I to VIIl.*

(ii) *The horizontal rows are called periods.*

(iii) *Groups I to VIII are sub-divided into subgroup A & B. Group 0 is the group of noble gases. Since noble gases were known at the time Mendeleev compiled his periodic table these were assigned group 0.*

(iv) *Two consecutive elements were expected to have a difference of at least one unit (and upto four units) in the atomic weights.*

(v) *Blank spaces were left for unknown elements. For example, blank space was left for Eka-silicon (germanium) and its properties predicted.*

(vi) *When table had no space for the known element on the basis of the properties, Mendeleev, without experimental evidence, changed its atomic weight by a factor that would change the atomic weight of the element to fill up gap in the table.*

Advantages of Mendeleev's Table

The modem version of the Mendeleev's periodic table has the following advantages:

(i) *The regular gradation in physico-chemical properties is similar in all the groups.*

(ii) *The group number (except for group VllI) gives the highest valence state possible for the elements.*

(iii) *Elements of the second row of group I, II and III show a diagonal relationship to the next elements of group Il, III and IV respectively.*

(iv) *From the positions of the gaps in the table, Mendeleev predicted the properties of the missing elements.*

(v) *Mendeleev used his periodic classification to rectify the atomic weights of elements. For example, he changed the atomic weights of Al and B from 40.5 and 16 to 27 and 10.7 respectively. Thus AI could fill the gap between Mg (24) and Si (28) whereas B could be placed between Be (9) and C (12).*

Defects / Limitations of Mendeleev's Table

Mendeleev's periodic table despite its advantages suffers from certain drawbacks. These are:

(i) *Position of hydrogen which resembles both alkali metals and halogens is not clear. Like alkali metals it gives H^+ ion while like halogens, it gives hydride.*

(ii) *Certain chemically similar elements, e.g., Cu and Hg or Au and Pt, are placed in different groups while some dissimilar groups are grouped together. For example, alkali metals, copper, silver and gold have been placed in the same group though they are dissimilar."*

(iii) *Lanthanides and actinides do not find any proper place in the table.*

(iv) *Certain elements of higher atomic weight, preceed others with lower atomic weight;*

Argon (40 preceeds potassium (39)

Cobalt (59) preceeds nickel (58.6)

(v) *No place is offered to isotopes and isobars in different groups.*

(vi) *No explanation is available for the stability of valence states differing by unit of two (inert pair effect).*

(vii) *No explanation is provided for the anomalous behavior of the first member of a group.*

MODERN PERIODIC LAW

On studying the shortcomings (limitations) in the Mendeleev's table, it became apparent that atomic weight is not the fundamental property of elements. There is something else in the structure of elements that brings about periodicity 'of properties in elements. The clue to this' problem was provided by Moseley who studied the characteristic X-ray spectra of elements.

Moseley's Work

In 1913, H.GJ. Moseley carried out the first detailed study of the characteristic spectra emitted by different elements. Using the Bragg crystal spectrometer, Moseley studied the spectra of 38 elements showed that the characteristic lines could be separated into Wo distinct series which then could be related to the K and L radiations observed earlier Barkla and Sadler (Barkla and Sadler studied the characteristic radiations around 1908). They studied the absorption properties and named more penetrating radiations, K-radiations and less penetrating radiations L-radiations.

Modern Periodic Table

The first comprehensive classification of elements was made independently by Dimitrii Mendeleev in Russia and Lother Meyer in Germany. While Lother Meyer was primarily interested in the relationships obtained by plotting the magnitude of physical properties against atomic weight. Mendeleev based his system of classification on chemical characterization as a periodic function of atomic weights the periodic law.

After an elucidation of atomic structure arid the discover of isotopes, it was realized that the atomic number of an element is a more fundamental property of an e element than the atomic weight. Thus in its revised form the periodic law is stated as:

"The properties of elements are periodic Junctions of their atomic number".

In other words, when the elements are listed in the order of increasing atomic numbers, elements having closely similar properties will fall at definite intervals along the list. This tabular arrangement of elements having similar properties laced in vertical columns is called as periodic table. A large number of versions large number of versions of the periodic table have been proposed but the one that is' easiest to use and which is most closely related to the electronic structures of the atoms is the so-called long form shown in Fig. 5. The long form of periodic table may regarded as an extended form of the Mendeleev's table.

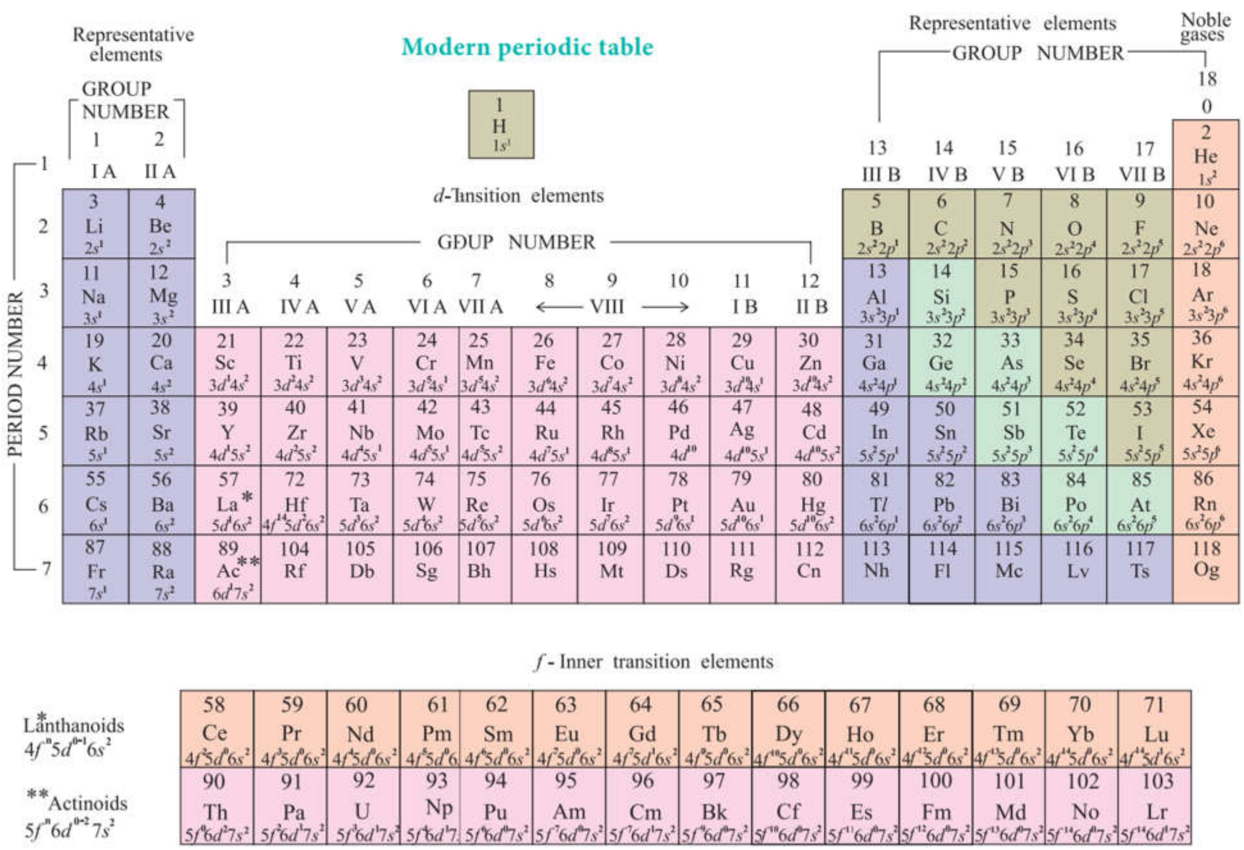

Fig 5. Moseley periodic table (long form)

The main features of the Bohr's long table are summarized as follows:

1. There are 18 vertical columns which constitute 16 groups of dements. These are numbered IA, IIA, IIIB, ...,., VIIB, VIIIB, IB, IIB, IIIA, ..., VIIA and zero (or VIIIA) according to the traditional system of nomenclature.

According to the new IUPAC (International Union of Pure and Applied Chemistry) recommendation adopted in 1984, the groups are numbered 1 to 18 as shown also in Fig. 1.1O. Thus, the alkali metal group IA becomes, 1; while group 2 is Be; Mg and other alkaline earths. The d-block elements are labeled from , group 3 (Sc, Y, La, Ac) to 12 (Zn, Cd, Hg). Thus Fe, Ru and Os constitute group 8, Co, Rh and Ir group 9 and Ni, Pd and Pt group 10. The boron group - B, AI, Ga, In and Tl becomes group 13 and the remaining main groups constitute upto group 18 - the noble gases. The numbering in the p-block thus differs from the old scheme by adding 10 and using Arabic instead of Roman numerals.

2. Elements of groups lA(l), IIA(2) , ITIA(13), IVA(l4); VA(15), VlA(16) and VIIA(17) have their outermost shells incomplete.' These are. called normal elements or representative elements or non-transition elements.

3. Elements of group IIIB(3), IVB(4), VB(5), VIB(6), VIlB(7) VIIIB(8, 9, 10), IB(ll) and IIB(12} are known as transition elements. These have their outermost as well as penultimate shell incomplete. The electrons in them occupy (*n* - *l*) d sub-shell in preference to np.

4. Elements of VIIIA or zero (18) show little reactivities and are termed as noble gases.

5. Horizontal rows are called periods. There are seven periods in the table:

(i) The first period is a short period of two elements (H - He).

(ii) Second and third are two short periods of 8 elements each (Li - Ne and

Na - Ar).

(iii) Fourth and fifth are long periods of 18 elements each(K - Kr and Rb – Xe while 'Sixth is a long period of 32 elements (Cs - Rn) including the rare earth elements (At. No. 57 - 71) which are all placed at the same row of the periodic table. These rare earths (Ce - Lu) are listed separately at the bottom of the table. Th ese are also known as lanthanides.

(iv) Seventh is an incomplete period of 23 element§. The 14 elements (Th - Lr) extracted from the seventh period are also placed at the bottom of the periodic table and are called actinides.

(v) The elements after Uranium (Z = 92) are called transuranic elements. These elements are the result of atomic research and hence are synthetic elements.

6. The noble gases have been grouped at the extreme right of the periodic table. In this table the long periods have been extended and short periods have been broken so as to accommodate the transition elements at their proper places.

Merits of the Long Form of the Periodic Table

The long form of the periodic table has a number of merits over the Mendeleev's periodic table in the following respects: ..

(i) *The classification of the elements is based on a more fundamental property viz. atomic number.*

(ii) *It relates the position of an element to the electronic arrangement in its atoms and is, therefore, nearly an ideal arrangement.*

(iii) *It reflects the similarities, differences and the. trends in the chemical properties more clearly across the long periods.*

(iv) *The inert gases having completely filled shells have been laced at the end of each period. Such a location of the inert gases represents a logical completion of each period.*

(v) *In this form of the periodic table, all the elements of the two sub-groups have been placed separately and thus dissimilar - elements do not fall together.*

(vi) *It provides a clear demarcation of different types 'of the elements like active metals, transition metals, non-metals, metalloids, inert gases, lanthanides an actinides·*

(vii) *The properties ·of transition elements are more clearly understood and their place in a long period is justified in the light of their electronic configuration.*

(viii) *The position of lanthanides and actinides as a separate group in the table, again, is based on their analogous chemical behavior.*

(ix) *It is easier to remember, understand and reproduce.*

Defects of the Long Form of Periodic Table

Although the long form of the periodic table is superior to Mendeleev's periodic table in many respects, it retains some of the defects as such. These are listed below:

(i) *The group nomenclature A and B as mentioned earlier is arbitrary and confusing. The designation is often inverted for groups III to VII. To overcome this problem use is being made of new IU'PAC nomenclature along with the traditional nomenclature.*

(ii) *The problem of the position of hydrogen still remains unsolved.*

(iii) *The presence of transition elements between sand p blocks interrupts the regular change in character along the sand p-blocks rows. There is little chemical justification for the presence of these elements between sand p-blocks.*

(iv) *Zn, Cd and Hg are not typical transition elements. They are in fact fairly typical representative elements, but do not fit easily into the scheme.*

(v) *In the long form of the periodic table there is no attempt to systematize the elements into the useful classification of metals and non-metals.*

(vi) *The terms usually associated with the elements in the long form of the table such as representative, transition, etc. should be regarded merely as convenient labels and have no definite associated meaning. .*

(vii) *Like the Mendeleev's table, it fails to accommodate the lanthanides and actinides in the main body of the table.*

(viii) *The arrangement is unable to reflect the .electronic configuration of many elements.*