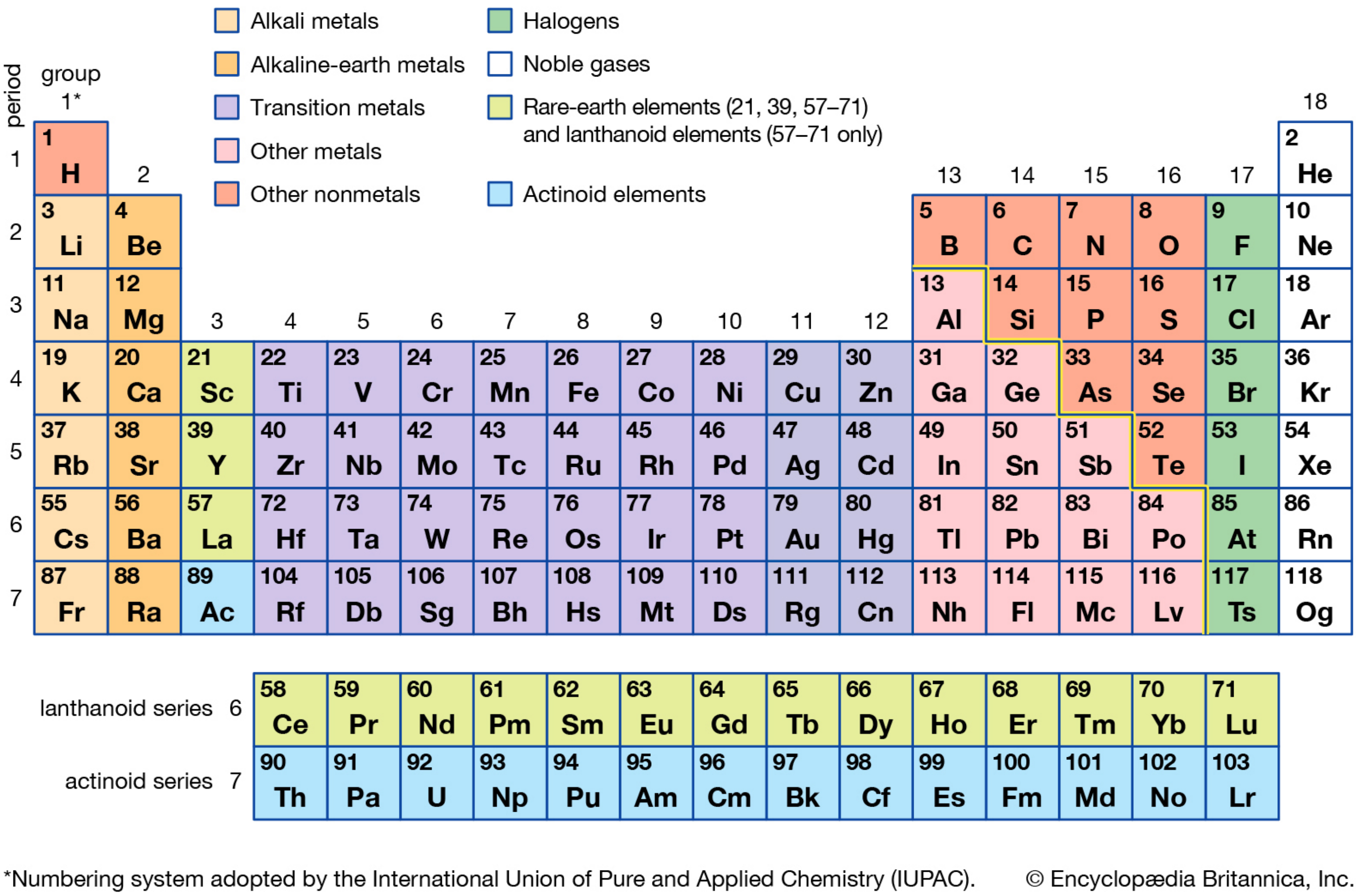
Modern Periodic Table, Group trends and periodic properties

Class: B.S II SS

Periodic table of the elements



Periodic Table

Mendeleef's Periodic Law and Mendeleef's Periodic Table

Attempts were made to classify the elements in a number of ways. Most noteworthy of these is that made by Russian chemist, Mendeleef (*men-de-h-lay-eff*) who gave a law known as *Mendeleef's Periodic Law* which states as :

The properties of elements are a periodic function of their atomic weights, i.e., if the elements are arranged in the increasing order of their atomic weights, the properties of the elements (i.e., similar elements) are repeated after definite regular intervals or periods.

Working on this law, Mendeleef arranged the elements in the increasing order of their atomic weights in the form of a table which is known as *Mendeleef's Periodic Table* after his name.

In this table the elements are arranged in *groups (or columns)* and *periods (or rows)*.

Defects of Mendeleef's Periodic Table

Mendeleef's periodic table suffers from the following defects :

1. Position of hydrogen. Hydrogen resembles both the alkali metals and the halogens. Its position in the periodic table is, therefore, anomalous.

2. Position of lanthanides and actinides. A group of 15 elements (At. No. 57 to 71) which is called rare earths or lanthanides does not find its proper place in the table and has been placed at one place in group III and period 6. Similarly, another group of 15 elements (At. No. 89 to 103) called actinides does not find its proper place and has been put at one place in group III and period 6.

3. Similar elements are separated while dissimilar elements are placed in the same group. Certain elements which possess similar properties are separated in the periodic table, as, for example, copper and mercury; silver and thalium; and barium and lead; while many dissimilar elements have been grouped together. For example Cu, Ag, and Au are grouped along with the alkali metals though there is little resemblance between them. Similarly manganese is grouped with the halogens.

4. Existence of four anomalous pairs of elements. The order of increasing atomic weight has been ignored in case of four pairs of elements in order to place them in a position justified by their properties. *Thus elements of higher atomic weights precede those of lower atomic weight at four places as shown below :*

(*a*) Ar (Z = 18, at. wt. = 40) precedes K (Z = 19, at. wt. = 39.0)

(*b*) Co (Z = 27, at. wt. = 59.9) precedes Ni (Z = 28, at. wt. = 58.6)

(*c*) Te (Z = 52, at. wt. = 127.6) precedes I (Z = 53, at. wt. = 126.9)

(*d*) Th (Z = 90, at. wt. = 232.12) precedes Pa (Z = 91, at. wt. = 231)

5. Position of isotopes. If the elements are arranged in the order of their increasing atomic weights, it is not possible to accommodate large number of *isotopes* in the periodic table.

6. Group does not represent valency. Excepting osmium, elements placed in group eight do not show a valency of 8. Also the elements lying in the middle of long periods show two or more valencies *e.g.* Cr, Mn etc.

Mosley's Modern Periodic Law

Mosley showed in 1911 that, since the physical and chemical properties of an element depend on the number of electrons and their arrangement in different orbitals of the atom, the classification of the elements should be based on the number of these electrons (*i.e.* atomic number) and their arrangement in different orbitals. This idea led Mosley to predict that most of the defects Of Mendeleef's periodic table disappear, if the basis of classification of elements is changed to atomic number in place of atomic weight. Accordingly, Mosley put forward Modern Periodic Law which states as follows :

The properties of elements are a periodic function of their atomic numbers, i.e. if the elements are arranged in the increasing order of their atomic numbers, the properties of the elements (i.e. similar elements) are repeated after definite regular intervals or periods.

With the replacement of atomic weight by atomic number as the basis of classification of elements, many of the irregularities in the Mendeleef's table disappear as shown below

1. Position of hydrogen. The dual role of hydrogen is explained by the fact that it has one electron in its outer orbit. It has equal tendency of gaining or losing one electron for assuming a stable configuration. When it loses one electron to give H^+ it resembles alkali metals (which give Li^+, Na^+, K^+, etc. ions) while when it gains one electron to give H^-, it resembles halogens (which give Cl^-. Br^- etc.).

2. Anomalous pairs of elements. This anomally disappears altogether and the pairs Ar—K, Co—Ni, Te—I and Th—Pa are found arranged in the table in the order in increasing atomic numbers as shown below :

Pairs of elements →	*Ar*	*K*	*Co*	*Ni*	*Th*	*I*	*Th*	*Pa*
Atomic numbers →	*18*	*19*	*27*	*28*	*52*	*53*	*90*	*91*
Atomic weights →	*40*	*39*	*59.9*	*58.6*	*127.6*	*126.9*	*232.12*	*231*

3. Position of rare earths. The arrangement of extranuclear electrons in all the rare earth elements can be represented as 2, 8, 18 (18 + *x*), 9, 2, where *x* varies from 0 (for La) to 14 (for Lu). With this general arrangement of electrons, all of them possess the same valency and similar chemical properties. This justifies their grouping at the same place.

4. **Position of isotopes.** Since isotopes of the same element possess the same atomic number, all of them should occupy one and the same place in the periodic table.

5. **Justification for dissimilar elements being placed together.** The length of the periods is determined by arrangement of electrons in different orbits. The end of every period results from the completion of the last orbit (last number is always an inert gas). Different periods carry 2, 8, 18 and 32 elements.

When 18 elements are to be distributed among 8 groups; groups 1—7 get two elements each while group 0 gets only one. The three elements which cannot be arranged elsewhere are placed in a special group VIII. This lack of space is enough *justification for group VIII*.

Out of the two elements which every long period adds to a group, one resembles the typical element, the other does not. This gives rise to the formation of sub-groups. This explains *why dissimilar elements have been grouped together*.

Extended or Long Form of Periodic Table : Modern Periodic Table

In order to remove the defects of Mendeleef's periodic table, a number of tables have been suggested from time to time by various workers for classifying the elements in the increasing order of their atomic numbers. Out of the various tables the *Extended Long Form of Periodic Table* is the most simple and is widely accepted.

This table is shown on the next page and is also called *Bohr's Periodic Table*, since it is based on Bohr's scheme of the classification of the elements into four types depending on the number of incomplete shells of electrons in the atom. This table was proposed by Rang (1893) and then modified by Werner (1905) and extended by Bury (1921).

Groups

The vertical columns shown in the periodic table are called *groups* or *families* or simply *columns*.

(*a*) There are *nine groups* in all including VIII group consisting of three triads (Fe, Co, Ni; Ru, Rh, Pd; Os, Ir, Pt.) and zero group of inert gases. Groups I to VII are sub-divided into sub-groups A and B. Thus there are 18 vertical columns which are: IA, IIA, III A, IVA, VA, VIA, VII A, zero, IB, II B, III B, IV B, VB, VI B, VII B and three columns of group VIII.

(*b*) Elements of groups IA, IIA, IIIA, IVA, VA, VIA and VII A have their *outermost shells incomplete while each of their inner shells is complete*. These elements are called *normal or representative elements*. These elements consist of some metals, all non-metals and metalloids.

(*c*) Elements of groups I B, II B, III B (only Sc, Y, La and Ac) IVB, VB, VIB, VIIB and VIII have their *two outermost shells incomplete*. These are called *transition elements*. These elements are placed in the middle of the table. All these elements are *metals*.

(*d*) Elements of group zero have *all their shells completely filled.* These elements are called *noble gases.* These are placed at the extreme right of the table.

(*e*) Two groups of 14 elements lying in group III B [Ce(Z = 58) to Lu (Z = 71) and Th (Z = 90) to Lw (Z = 103)] have their *three outermost shells incomplete*. These are called *lanthanides* and *actinides* respectively and have been placed at the bottom of the table.

Periods

The horizontal rows shown in the periodic table are called *periods* or simply *rows*. There are *seven periods* in the table.

(*a*) *1st* period consists of 2 elements which are H (Z = 1) and He (Z = 2).

(*b*) *2nd* and *3rd* periods have 8 elements each.

2nd period → Li (Z = 3) to Ne (Z = 10)

3rd period → Na (Z = 11) to Ar (Z = 18)

Both these periods are called *short periods.* The elements of *2nd* and *3rd* short periods were called *typical elements* by Mendeleef as these elements were considered to be the true representatives of their respective groups. But, now since it has been found that the elements of *2nd* period resemble more with the elements diagonally related to them than with the elements of their own groups, the elements of *2nd* period are not considered as true representatives of their respective groups. Now a days the elements of only *3rd period namely Na, Mg, Al, Si, P, S, Cl are called typical elements*. These elements have the following characteristics :

(*i*) They show their group characteristics as valency, chemical behaviour etc.

(*ii*) They form a connecting link between the first member of their respective groups and with the elements of B sub-groups. Hence these elements serve as a bridge between the two sub-groups. However, they show very little resemblance with elements of B sub-groups. For example Na and Cl which are the typical elements of I and VII groups respectively, resemble more closely with the elements of their own sub-groups and show a very little resemblance with the elements of B sub-groups.

(*c*) *4th* and *5th* periods have 18 elements each while *6th* period has 32 elements as shown below :

4th period → K (Z=19) to Kr (Z=36)

5th period → Rb (Z=37) to Xe(Z=54)

6th period → Cs (Z=55) to Rn (Z=86)

All these three periods are called *long periods. 6th* period also includes 14 rare earths or lanthanides [Ce (Z=58) to Lu (Z=71)].

(*d*) *7th* period is an incomplete period and at present it consists of 19 elements which are Fr (Z=87) to Ha (Z= 105). All the elements of this period are radioactive. This period also includes 14 actinides [Th (Z=90) to Lw (Z = 103)]. The elements after U (Z=92) are called *transuranic elements.* These elements are the result of atomic research and hence are synthetic elements.

Thus we see that in this table the long periods have keen extended and short periods have been broken so as to accommodate the transitional elements in the long periods at their proper places between groups II A and III A.

General Characteristics of Groups

1. Number of valency electrons. On moving down a given group the number of valency electrons does not change, *i.e.* remains the same.

2. Valency. The valencies of all the elements of the same group are the same. The valency of an element with respect to oxygen is equal to its group number.

3. Properties of elements. All the elements of a given group possess very similar physical and chemical properties. There is a regular gradation in their properties when we move from top to bottom in a group. For example :

(*a*) The alkali metals (group IA) resemble each other and their base-forming tendency increases from Li to Cs.

(*b*) The reactivity of halogens (group VII A) decreases as we pass from F to I.

4. Size of atoms. *Size of atoms increases on descending a group.* For example in group IA, atomic size increases from Li to Cs. Thus :

$$Li < Na < K < Rb < Cs$$

5. Metallic character. *The metallic character of the elements increases in moving from top to bottom in a group.* This is particularly apparent in groups IVA, VA and VIA, which begin with non-metals (namely C, N and O respectively), and end with metals (namely Pb, Bi and Po respectively). For example, in group VA, N and P are non-metals, As and Sb are metalloids and Bi is a typical metal. Thus the metallic character of these elements increases from N to Bi as shown below :

Elements of group VA :	*N,P,*	*As, Sb,*	*Bi*
	Non-metals	*Metalloids*	*Metal*
Metallic character :	*—Metallic character increasing→*		

It is because of a gradual increase of the metallic character of the elements from top to bottom that the *oxides of the elements become more and more basic in the same direction.* For example :

Oxides of the elements of group VA :	N_2O_3, P_2O_5,	As_2O_3, Sb_2O_3,	Bi_2O_3
	Acidic	*Amphoteric*	*Basic*
Basic character :	*—Basic character increasing→*		

6. Number of electron shells. *In going down a group the number of electron shells increases by one at each step and ultimately becomes equal to the number of the period to which the element belongs* as shown below for the elements of Group IA.

Elements	*Electronic configuration*	*No. of shells*
Li	*2, 1*	*2*
Na	*2, 8, 1*	*3*

K	*2, 8, 8, 1*	*4*
Rb	*2, 8, 18, 8, 1*	*5*
Cs	*2, 8, 18, 18, 8, 1*	*6*
Fr	*2, 8, 18, 32, 18, 8, 1*	*7*

General Characteristics of Periods

1. Number of valency electrons. Number of valency electrons increases from 1 to 8 when we proceed from left to right in a period.

2. Valency. The valency of the elements with respect to (w.r.t.) hydrogen in each short period increases from 1 to 4 and then falls to one while the same with respect to oxygen increases from 1 to 7 as shown below for the elements of *2nd* and *3rd* period :

Elements of 2nd period :	*Li*	*Be*	*B*	*C*	*N*	*O*	*F*
Hydrides of the elements :	LiH	BeH_2	BH_3	CH_4	NH_3	H_2O	HF
Valency of the elements w.r.t hydrogen :	*1*	*2*	*3*	*4*	*3*	*2*	*1*
Elements of 3rd period :	*Na*	*Mg*	*Al*	*Si*	*P*	*S*	*Cl*
Oxides of the elements :	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl_2O_7
Valency of the elements w.r.t. oxygen :	*1*	*2*	*3*	*4*	*5*	*6*	*7*

3. Size of atoms. *Size of atoms decreases from left to right in a period*. Thus alkali metals have the largest size while the halogens have the smallest size.

4. Properties of elements. The properties of the elements of a given period differ considerably but the elements in the two adjacent periods show marked similarity between them. For example, when we consider the elements of *2nd* and *3rd* periods, we find that Na resembles Li, Mg resembles Be, Al resembles B, Si resembles C, P resembles N, S resembles O, Cl resembles F and Ar resembles Ne.

5. Metallic character. On moving from left to right in a period the metallic character of the elements decreases. For example in *3rd* period, Na, Mg and Al are *metals* while Si, P, S and Cl are *non-metals* as shown below :

Elements of 3rd period :	Na, Mg, Al	Si, P, S, Cl
	Metals	*Non-metals*
Metallic character :	*—Metallic character decreasing→*	

It is because of the gradual decrease of the metallic character from left to right that the oxides of the elements become less and less basic in the same direction. For example :

Oxides of the elements of 3rd period :	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl_2O_7
Basic character :	*Strongly basic*	*Basic*	*Amphoteric*	*Feebly acidic*	*Acidic*	*More acidic*	*Most acidic*

—Basic character decreasing→