Chapter - 5
PERIODIC CLASSIFICATION OF ELEMENTS

Introduction: It is very difficult to study individually the chemistry of all the elements and millions of their compounds, hence to simplify and systematize the study of chemistry of the elements and their compounds, they have been arranged in a tabular form with the help of groups & periods.

Dobereiner's triads: It was the first attempt towards classification. He arranged similar elements in a group of three elements called triad and the atomic weight of the middle elements of the traid is approximately the arithmetic mean of the other two.

e.g. Ca^{40} $Sr^{87.5}$ Ba^{137} $Cl^{35.5}$ Br^{80} I^{127}

At. wt. of Sr = $\frac{137+40}{2} = 88.5$ At. wt. of Br = $\frac{35.5+127}{2} = 81.25$

88.5 is nearly similar to 87.5 of atomic weight of Sr. 81.25 is nearly similar to 80.

Newland's law of octaves: When the lighter elements are arranged in order of their increasing atomic weights, then every eighth element are similar to the first element in their properties, similarly as the eighth note of a musical instrument is similar to 1st one. e.g. Na 8th element resembles in their properties with Li. Similarly K the 8th element with Na and so on. By that time noble gases were not discovered.

Lother Meyer arrangement: According to him the elements which are similar in their chemistry occupied similar positions on the graph of atomic volume vs atomic weights e.g. (a). The alkali metals occupy the peaks on the curve while alkaline earth metals occupy the descending position on the curve. (b) Halogens occupy the ascending positions on the curve.

Mendeleev's periodic law: Initially he proposed that the chemical properties of the elements are the periodic function of their atomic weights.

But later on, he modified the statement after considering the Lother Meyer's work. Now the combined statement is called Mandeleev's periodic law "The physical and chemical properties of the elements are the periodic function of their atomic weights".

Periodic table: The table which classifies all the known elements in accordance with their properties in such a way that the elements with similar properties are grouped together in the same group while dissimilar elements are in the other group.

Merits of Mendeleev's periodic table:

(a) Study of elements and their compounds becomes easy and systematic, as by knowing the property of one element in a group, the properties of the other elements present in the same group can easily be predicted.

(b) Helps in the discovery of new elements. As Mendeleev's left 12 blank spaces for some unknown elements and further, predicted the properties of these elements e.g. eka aluminium, (1875) ekasilicon (1886), Ga, Ge & Se were discovered later on.

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 H 1.008	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.003
3 Li 6.939	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.183
11 Na 22.99	12 Mg 24.312	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.064	17 Cl 35.453	18 Ar 39.948
19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.9	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.71	29 Cu 63.546	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc [97]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.4	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.91	56 Ba 137.34	57* La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po 210	85 At 210	86 Rn 222
87 Fr 215	88 Ra 226.03	89** Ac 227.03	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [269]	109 Mt [268]	110 [271]	111 [272]	112 [277]		114 [289]		116 [289]		

*Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 145	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
**Actinides	90 Th 232.04	91 Pa 231	92 U 238.03	93 Np 237.05	94 Pu 239.05	95 Am 241.06	96 Cm 244.06	97 Bk 249.08	98 Cf 252.08	99 Es 252.08	100 Fm 257.1	101 Md 258.1	102 No 259.1	103 Lr 262.11

(c) Correction of doubtful atomic mass.

(d) Correction of the valency of some element.

(e) Correction in the position of some elements.

Defects in the Mendeleev's periodic table:

(i) Position of hydrogen is anomalous as it resembles with 1st group alkali metal and also with 7th group halogen in their properties.

(ii) Position of isotopes: Isotopes must have different positions but they are placed in the same group.

(iii) Position of isobars : Are placed in different groups.

(iv) Dissimilar elements are placed together in the same group like K & Cu in 1st group.

(v) Similar elements placed in different groups.

(vi) Some higher atomic weight elements placed before the lower atomic weight elements e.g. Ar^{40} precedes K^{39}, $Co^{58.9}$ precedes $Ni^{58.7}$, $Te^{127.6}$ precedes I^{127}, Th^{232} preceds Pa^{231}.

(vii) Position of metals and non-metals: Both are placed together in the same group.

(viii) Diagonal relationship could not be explained.

(ix) Lanthanides and actinides were placed separately at the bottom of the periodic table.

(x) No proper position to VIII-th group elements.

(xi) Position of noble elements.

(xiii) Existence of variable valency could not be explained.

(xiv) Cause of periodicity can not be explained.

Classification of elements according to their atomic number

In 1913 Mosley from his observation on the X-ray spectra on a number of elements, came to the conclusion that atomic number is more accurate in the identification of an element than its atomic weight. Moreover the atomic number of an element is its serial number or position number in the periodic table. Hence elements are arranged in the ascending order of their atomic numbers in the modern periodic table.

MODERN PERIODIC LAW

(a) The properties of elements are the periodic function of their atomic numbers.

(b) The properties of the elements depend upon their electronic configuration.

THE MODERN PERIODIC TABLE

The modern periodic table is divided horizontally into periods from left to right whereas vertically it is divided into columns called groups.

(i) There are seven periods in this table. The first period contains 2 elements. The second and third periods contain 8 elements each. These two periods are known as short periods. Fourth and fifth periods each contains 18 elements, while sixth period contains 32 elements. Seventh period is incomplete.

(ii) There are 18 groups in the modern periodic table.

Let us now examine critically the relation between the electronic configuration of an element and its position in the long form of periodic table.

(1) **The first period :** Contains two elements – H and He. Since their principal quantum number is 1(n = 1) which contains only *s*-orbital having maximum occupancy of 2 electrons, this period can not accommodate more than two elements e.g., H = $1s^1$ and He = $1s^2$.

(2) **The second period :** The principal quantum number of the second period is two (n = 2). Since this principal quantum number can have two subshells *s* and *p* which can contain maximum of 2 and 6 electrons respectively, the total number of elements in the second period is 8. The period begins with Li ($1s^2$, $2s^1$), and then electrons are filled up one by one and is completed in Ne ($1s^2$ $2s^2$ $2p^6$). Hence 8 elements are there in the second period.

(3) **The third period :** The principal quantum number of the third period is three (n = 3). It begins with Na ($1s^2$ $2s^2$ $2p^6$ $3s^1$) and ends with Ar ($1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$) containing 8 elements having s and p orbitals.

(4) **The fourth period :** The principal quantum number of fourth period is four (n = 4). It begins with K ($1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^1$) and ends with Kr ($1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^{10}$ $4s^2$ $4p^6$). The fourth period is the first long period which contains 18 elements.

(5) **The fifth period :** The principal quantum number of fifth period is five (n = 5). It begins with Rb and ends with Xe. The electronic configurations of the outermost shell of Rb and Xe are $5s^1$ and $5s^2$ $5p^6$ respectively. It is the second long period which contains 18 electrons.

(6) **The sixth period :** The principal quantum number of sixth period is six (n = 6). It begins with the alkali metal Cs ($6s^1$) and ends in Rn ($6s^2$ $6p^6$).

(7) **The seventh period :** This principal quantum number of sixth period is seven (n = 7). This period is repetition of the sixth period having 19 elements so far discovered.

Types of Elements

(1) **Type – 1 – Inert gas elements :** Elements with outermost shell electronic configuration ns^2np^6 [except He ($1s^2$)] are called inert gas elements. There are altogether six inert gas elements – He (2), Ne (10), Ar (18), Kr (36), Xe (54) and Rn (86). Because of the stability of their electronic configurations, these elements do not enter into ordinary chemical reactions. These elements belong to group 18 of the periodic table.

(2) **Type – II – Representative elements :** Elements with outermost electronic configuration ns^1 to ns^2 np^5 belong to this category. Elements of Groups 1, 2, 13, 14, 15, 16 and 17 are the members of this class. The elements of this type are chemically active. They tend to enter into chemical combination either by sharing or losing or gaining electrons to attain the electronic configuration ns^2 np^6 for the outermost shell. The name representative has been assigned to these elements because of their frequent occurrence in nature and because they typify the properties of all other elements of the group to which they belong.

(3) **Type – III – Transition elements :** An element having incomplete 'd' shell either in ground state or in the most stable valency state, is called a transition element. These elements are also called d-block elements.

There are 30 transition elements, divided into 4 series corresponding to 3d, 4d, 5d and 6d orbitals. The series begins with Group 3 elements Sc, Y, La and Ac and ends with Cu, Ag, Au and Ha (105) (incomplete). The transition elements exhibit striking similarities with each other.

(4) **Type – IV – Inner transition elements :** In these elements either in their ground state or in any of their common oxidation state the last electron goes to the *f* orbital of antepenultimate shell i.e., the last electron enters $(n-2)f$ sub-shell. As a result $(n-2)f$ subshell is progressively filled. The general electronic configuration of the valence shell of this type of element is $(n-2)\,f^{1-14}.(n-1)\,s^2p^6d^{0\text{ or }1}\,ns^2$. These elements differ in atomic numbers but exhibit properties like a single element. They are trivalent having similar chemical properties. Hence they have been placed below in the modern periodic table in a separate group of elements.

Classification of elements into s, p, d and f blocks

(1) **s-block elements :** In the atoms of s-block elements, the last electron enters the s-orbital of the outermost shell. Thus the last electron enters the ns orbital and as a result, these elements have either ns^1 or ns^2 configurations in the ground state. The elements of Group 1 and Group 2 belong to this block. s-block elements are placed at the extreme left in the periodic table.

(2) **p-block elements :** In the atoms of p-block elements, the last electron enters the p-orbital of the outermost shell. Thus the last electron enters the np orbital and as a result the general electronic configuration of the outermost shell of these element is $ns^2\,np^{1-6}$, p-block elements occupy groups 13, 14, 15, 16, 17 and 18 zero having electronic configuration $ns^2\,np^1$ to $ns^2\,np^6$.

(3) **d-block elements (Transition elements) :** In these elements, the last electron goes to $(n-1)d$ orbital i.e., the last electron goes to the penultimate shell. As the $(n-1)d$ orbital of these elements is progressively filled they are called *d*-block elements.

The d-block elements occupy group 3, 4, 5, 6, 7, 8, 9 and 10. They occupy the middle of the periodic table between s and p-block elements.

(4) **f-block elements :** Elements having the general electronic configuration of valence shell $(n-2)f^{1-14}(n-1)s^2\,p^6\,d^{1\text{ or }0}\,ns^2$ are called *f*-block elements. In these elements in their atomic state or in their common oxidation state, the last electron enters the $(n-2)f$ orbital and as a result the $(n-2)$ orbital of these elements are progressively filled. Hence the name *f*-block elements. Lanthanides $(4f^{1-14})$ and actinides (Th to Lw) having 5*f* orbital belong to this block.

Characteristics of Periodic Table

Periodicity of properties of elements : According to the modern periodic law, the properties of elements are periodic functions of their atomic numbers. The word 'period' indicates that with the increase of atomic numbers of the elements in the same period or group, there is a gradual variation in a particular property of the elements.

(i) **Density :** It is observed that the density increases from left, then reaches a maximum in the central position and then decreases with the rise of atomic number. In a group, density increases from top to bottom.

(ii) **Atomic radius or atomic size :** Atomic radius is defined as the distance between the centre of the nucleus and the outermost shell of the atom.

Variation in a period : The radius of atoms decreases progressively from left to right up to group 17 and then increases suddenly in the noble gases.

Explanation : As we move from left to right across a period, the atomic number increases with the increase in the positive charge on the nucleus, but the outer electron shell remains same resulting in increase in attraction and thus a decrease in the atomic radius. This effect continues up to group 17. The abrupt increase in atomic radius of 18 group elements is due to the fact that the radius of the noble gases are not covalent radii but are Vander Waal's radii.

Variation in the group : With the rise of atomic number as we go down in a group, the atomic radius generally increases.

Explanation : The increase of atomic radius from top to bottom is due to the addition of new quantum shell, as a result the distance between the nucleus and the outermost electron increases.

(iii) **Metallic and Non-metallic Character :**

The tendency of an element to lose electron(s) to produce a cation is called its electropositive or metallic character.

In a period : Thus, as we move from left to right across a period, the metallic character of an element decreases and non-metallic character increases.

In a group : As we move from top to bottom in a group, the metallic character of the elements increases.

(iv) **Ionisation potential :**

The first ionisation potential of an element is defined as the amount of energy necessary to remove the outermost electron i.e., most loosely bound one, from its isolated gaseous atom in its lowest energy state, against the force of attraction existing between the nucleus and that electron, so as to give a cation, in the gaseous state.

Variation in a period :

As we move from left to the right across a period, the ionisation potential of elements increases with the rise of atomic number with some fluctuations. This is attributed to the decreased atomic radius coupled with increased effective nuclear charge as a result of which the force of attraction between the nucleus and the outermost electron increases. The ionisation potential becomes maximum for the noble gases which is due to their stable electronic configuration as well as maximum effective nuclear charge in a period.

Variation along a group :

As we move down a group the ionisation potential normally decreases. This is primarily due to the increased atomic radius as a new quantum shell is added on going down a group.

(v) **Electron Affinity :**

The electron affinity of an atom is the amount of energy released by an isolated neutral gaseous atom in its ground state (lowest energy state), when it captures an electron to form a uni negative ion.

Variation in a period :

As we move from left to the right along a period, the electron affinity of elements increases. This is due to the decrease of atomic radius coupled with increased effective nuclear charge. In general, electron affinity follows the following trend – Halogens > Oxygen family > Nitrogen family > Metals of group I and III > non metal of group IV > metals of group II.

Variation along a group :

As we move from top to bottom in a group, the electron affinity decreases which is due to their increased size. Halogens have exceptionally high values of electron affinity.

(vi) **Electronegativity :**

According to Linus Pauling, electro-negativity of an atom in a molecule is defined as its relative power to attract the shared electron pair in a covalent bond towards itself.

Variation in a period :

As we move from left to right along a period, the electronegativity of elements increases with the rise of atomic numbers.

Variation in a group :

In a group as we go down, electronegativity decreases. This is primarily due to increase of atomic radius. Though the effective nuclear charge increases, the increase of atomic radius outweighs this effect.

ASSIGNMENT

I. Multiple Choice Questions

1. Elements belonging of the same group have similar properties because

(a) they have similar electronic configuration of the outermost shell

(b) their atomic numbers go on increasing as we move down the group

(c) all of them are metallic elements

(d) none of the above

2. Which of the following elements has highest first ionization potential?

(a) C (b) N (c) B (d) O

3. Pair having elements from same period is

(a) Na, Ca (b) Na, Cl (c) Ca, Cl (d) Cl, Br

4. The property which generally decrease along a period is

(a) Ionization energy (b) Electron affinity (c) Metallic character (d) Valency

5. Element having the highest electron affinity is

(a) Br (b) Cl (c) I (d) F

6. The attempt for classified elements by plotting the atomic masses of elements against the volume was made by

(a) Dobereiner (b) Newland (c) Lother Meyer (d) Mendeleeff

7. Mark the group which has maximum number of elements in Mendeleeff's periodic table

(a) I (b) II (c) III (d) IV

8. The no. of elements in fifth period of periodic table is

(a) 8 (b) 32 (c) 18 (d) 19

9. The most electronegative element is

(a) nitrogen (b) fluorine (c) oxygen (d) chlorine

II. Fill in the blanks

(i) The energy released when electron is added to a neutral gaseous atom is called _____ of the atom.

(ii) Inert gases have _____ radii hence there is a sudden increase in atomic radii as we move to end of a period.

(iii) The amount of energy required to remove the most loosely bound electron from an atom is called its _____.

(iv) Atomic radius _____ from top to bottom in a group.

(v) Ionisation potential _____ on going down a group.

III. True / False

(i) The energy is released when a cation is formed from neutral atom.

(ii) All transition elements are metals.

(iii) Metallic character increases in moving down a group from top to bottom.

(iv) The electron affinity of fluorine is highest among halogens.

(v) The ionisation potential of Mg is larger than Na.

IV. Subjective Type Questions

Explain why :

1. In a period, the size of the atom decreases with the increase of atomic number but at the end of each period, in the noble gas, the atomic size increases abruptly.

2. Potassium is more electropositive than sodium

3. Chlorine can be converted to Cl^- ion more easily as compared to F^- ion from fluorine.

4. Bromine is less electronegative than chlorine.

5. Oxygen (at no.8) has a lower ionisation energy than that of nitrogen (at no.7)

6. s-block elements are very reactive.

7. Noble gases have zero electrons affinity.

8. Arrange the following in increasing order of the property indicated -

(i) F, Cl, Br and I (electron affinity)

(ii) Mg, Al, Si and Na (Ionisation potential)

(iii) F, Cl, Br and I (electronegativity)

ANSWERS

I. Multiple Choice Questions :

1. (a) **2.** (b) **3.** (b) **4.** (c) **5.** (b)

6. (b) **7.** (c) **8.** (c) **9.** (b)

II. Fill in the blanks :

(i) electron affinity

(ii) vander waal's

(iii) ionisation energy

(iv) increases

(v) decreases

III. True / False

(i) False

(ii) True

(iii) True

(iv) False

(v) True

IV. Subjective Type Questions

8. (i) I < Br < F < Cl

(ii) Na < Mg > Al < Si

(iii) I < Br < Cl < F