Classification of elements and Periodicity in Properties

Q. Why do we need to classify elements.

An. It become very difficult to study individually the chemistry of all the known elements and millions of their compounds. At this stage scientist felt the need of some simple method to systematize the study of the properties of various elements and their compounds. The arrangement of elements is called classification of elements and led to formulation of a periodic table.

Periodic table may be defined as the table which classifies all the known elements in accordance with their properties in such a way that elements with similar properties are grouped together in the same vertical column and dissimilar elements are seperated from one another.

— Doebereiner's triads :- He arranged similar elements in a group of three and showed that their atomic weight were either nearly the same or the atomic weight of the middle element was approximately the arithmetic mean of the other two. These group of three elements were called Doeberiner's triads and this law called law of triads.

The major drawback of this classification was that the concept of triads could be applied only to a limited number of elements. (Iron, cobalt, Nickel) (Lithium, Sodium, Potassium) (Chlorine, Bromine, Iodine) (Calcium, Strontium, Barium)

— Telluric Screw (or Helix) :- the first real periodic classification was the telluric screw proposed by A.E.B. de Chancourtois, in 1862. He arrange that known elements in order of increasing atomic weight and made a cylinderical table of element to display the periodic repetition of properties.

— Newland law of octaves :- When the lighter element were arranged in order of their increasing atomic weight, the.

Properties of every eighth element were similar to those of the first one like the eighth note of a musical scale. this generalization was called newland's law of octaves.

This generalization was failed, It was applicable to only lighter elements having atomic weight upto 40 u.

— Lothar-Meyer arrangement: He plotted a graph between the atomic volume and atomic weight of the elements and observed that the elements with similar properties occupied similar position on the curve.

He says that the physical properties of the elements are a periodic function of their atomic weight.

— Mandeleev's Periodic :- The Physical and chemical Properties of elements are a periodic function of their atomic weight. When the elements are arrange in order of their increasing atomic weight, elements with similar properties are repeated after certain regular intervals. this repetition of properties of element after certain regular intervals is called periodicity of properties.

— Significance of mandeleev's Periodic table.

1. Systematic study of the element.
2. Prediction of new elements.
3. Correction of doubtful atomic weight.

— Defects of mandeleev's Periodic table

1. Anomalous Position of hydrogen — the position of hydrogen in the periodic table is not fixed but is controversial.
2. Anomalous Pairs of element — Some element with higher atomic weight Precede the element with lower weight and no justification has been Provided.

3. Position of isotopes — Isotopes are the atoms of the same element having different atomic weight. According to classification these should be placed at different places. However isotopes of an element have not been given different places in the periodic table.

4. Some dissimilar elements are grouped together while some similar elements are placed in different groups.

5. Position of elements in group VIII — no proper place has been allotted to nine elements of group VIII which has been arranged in three triads, without any justification.

— Modern Periodic law — It states that physical and chemical properties of the elements are a periodic function of their atomic number. If the elements are arranged in order of their increasing atomic number the elements with similar properties are repeated after certain regular intervals.

The cause of periodicity in properties is the repetition of similar outer electronic configurations after certain regular intervals. These regular intervels being 2, 8, 8, 18, 18, 32. These numbers are also sometimes called magic numbers.

The table which is most commonly used these days and which is based upon the electronic configuration of elements is called the Present form or the Long form of the periodic table.

The long form of periodic table consists of eighteen vertical columns and seven horizontal rows. these vertical columns are known as group or families and the horizontal rows are called periods. Further 14 elements of sixth period called the lanthanoids and 14 elements of seventh period called Actinoids are placed in separate panels at the bottom.

– IUPAC Nomenclature of elements with atomic number Z > 100

Digit.	0	1	2	3	4	5	6	7	8	9
Root.	nil	un	bi	tri	quad	pent	hex	sept	oct	enn
Abbreviation	n	u	b	t	q	p	h	s	o	e

– Electronic Configuration of elements and the Periodic table –
The distribution of electrons into various orbitals of an atom is called its electronic Configuration.
Division of elements into s, p, d, f blocks and their electronic Configuration.
This division is based upon the name of the orbital which receive the last electron.

1. S-Block elements – Elements in which the last electron enters the s-orbital of their respective outermost shell are Called s-block elements.
thus the elements of group 1 and 2, including hydrogen and helium in which the s-orbitals are being Progressively filled are Called s-block elements.
General outer shell electronic Configuration of s-block elements is ns^{1-2} where $n = 2-7$.
General characteristics of S-Block elements.
(a) They have low ionization energies and are highly electro Positive.
(b) They are soft metals with low melting and boiling Point.
(c) They lose the valance electrons readily to form +1 in Case of alkali metals and +2 ions in Case of alkaline earth metals.
(d) They are very reactive metals. The metallic character and the reactivity increases as we move down the group. so they are never found Pure in nature.
(e) The Compound of s-block elements with the exception of

those of beryllium are predominantly ionic.

(f) most of the metals (except Be, Mg) of this block impart characteristic colours of the flame.

(g) They are strong reducing agents.

(h) All are good conductors of heat and electricity.

2 P-Block elements: Elements in which the last electron enters any one of the three P-orbitals of their respective outermost shell are called P-block elements.

Thus the elements of 13, 14, 15, 16, 17, 18 are called P-block elements.

General outer shell electronic configuration of P-block elements: $ns^2 np^{1-6}$ where $n = 2-6$

The elements of group 17 are called halogens and group 16 are called chalcogens.

The elements of S-block and P-block are collectively called representative or normal or main group element.

General characteristic of P-block elements.

(a) The metallic character increases from top to bottom within a group and non-metallic character increases from left to right along a period in this block.

(b) Their ionization energies are relatively higher as compared to those of S-block elements.

(c) They mostly forms covalent compounds.

(d) Some of them show more than one oxidation state in their compounds.

(e) Their oxidising character increases from left to right in a period and reducing character increases from top to bottom in a group.

3:- d-block elements.— elements in which the last electron enters any one of the five d-orbitals of their respective shells are called d-block elements

therefore in all there are ten vertical column comprising ten groups of d-block elements namely, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

General outer shell configuration of d-block elements are: $(n-1)d^{1-10}\ ns^{0-2}$, where $n = 4-7$.

These elements are also called transition elements

General characteristics of d-block elements.

(a) They are hard, malleable, ductile metals with high melting and boiling point.
(b) They are good conductor of heat and electricity.
(c) Their ionization energies are between s and p block elements
(d) They show variable oxidation states.
(e) They form both ionic and covalent compounds.
(f) Their compounds are generally coloured and paramagnetic
(g) They form coloured complexes.
(h) most of the transition metals and their compounds are used as catalysts.
(i) Most of the transition metals forms alloys.
(j) Zn, Cd and Hg which have the $(n-1)d^{10}\ ns^{2}$ electronic configuration, donot show most of the properties of transition elements.

—4. f-block elements :- elements in which the last electron enters any one of the seven-f orbitals of their respective shell are called f-block elements.

General outer shell electronic configuration of f-block elements are. $(n-2)f^{1-14}(n-1)d^{1-10}\ ns^{2}$, $n = 6-7$

there are two series of f-block elements each containing 14 elements

The elements of first series, cerium to lutetium which form a part of the sixth period are called Lanthanides. These are also called rare earth elements.

The elements of the second series, thorium to lawrencium which forms a part of the incomplete seventh period are called actinides. All the actinoids are radioactive elements. Elements from Neptunium to Lawrencium have been prepared artificially through nuclear reaction. ($_{93}Np - _{103}Lr$)
These 11 elements are called transuranic elements.
All the f-block elements are called inner transition elements.

General characteristics of f-block elements.

(a) They are heavy metals.
(b) They have generally high melting and boiling point.
(c) They show variable oxidation state.
(d) Their compounds are generally coloured.
(e) They have a high tendency to form complexes.
(f) Most of the elements of the actinide series are radioactive.

— Advantage of the present form of periodic table.

(1) It relates the position of an element in the table to its electronic configuration more clearly.
(2) It is easy to remember and reproduce all the elements more easily in sequence of atomic numbers.
(3) The elements in the same group show similar electronic configuration so there is a logical classification of group in it.
(4) The elements are classified into normal elements and transition elements on the basis of their electronic configurations.
(5) The elements are also classified as active metals, heavy metals and non-metals.

— Defects of the long form of periodic table.

(i) Position of hydrogen is not settled.
(ii) Lanthanids and Actinides have not been accommodated.

in the main body of this Periodic table.

— Prediction of Period, Group and Block of a given element.

(I) The Period of an element Corresponds to the Principle Quantum number of the valance shell.

(II) The block of an element Corresponds to the type of orbital which receive the last electron.

(III) The group of an element is Predicted from the number of electrons in the valance shell

— Periodic Properties — The Properties which are directly or indirectly related to their electronic Configuration and which show a regular gradation when we move from left to right in a Period or from top to bottom in a group are called Periodic Properties.

— Atomic radius :- The distance from the Centre of the nucleus to the Point upto which the density of the electron cloud is maximum.

— Covalent radius — It is defined as one-half the distance between the nuclei of two covalently boned atoms of the same element in a molecule

— Van-der walls radius :- It is defined as one-half the distance between the nuclei of two identical non-bonded isolated atoms or two adjacent identical atoms blonging to two neighbouring molecules of an element in the solid state.

— Metallic bond :- According to electron-sea model, a metal lattic Consists of Positive Kernels or metal ions arranged in a definite Pattern in a sea of mobile valance electrons. thus each Kernel (metal ion) is simultaneously attracted by a number of mobile electrons and each mobile electron is attracted by a number of metal ion. This force of attraction between the mobile electrons and the positive kernels is called the metallic bond.

— Metallic radius :- It is defined as one half the intermolecular distance between the two adjacent metal ions in the metallic lattice.

Vanderwall radius > metallic radius > covalent radius.

(i) Variation along a Period :- the Covalent or Vanderwalls radius decrease with increase in atomic number as we move from left to right.
(ii) Variation within a group — The atomic radius of element increase with increase in atomic number as we move from top to bottom in a group.

— Ionic radius — It may be defined as the effective distance from the Center of the nucleus of the ion upto which it exerts its influence on its electronic cloud.
(a) The radius of the Cation is always smaller then that of its Parent atom. because (i) decrease in the no. of shell (ii) increase in the effective nuclear charg resulting in greater force of attraction by the nucleus on the electron.
(b) The radius of the anion is always larger than that of its Parent atom.

— Isoelectronic ions :- ions of the different elements which have the same number of electrons but different magnitude of the nuclear charg are called isoelectronic ion. ionic radius of isoelectronic ion decrease with the increase in the magnitude of the nuclear charg.

– Ionization Enthalpy :- The minimum amount of energy required to remove the most loosely bound electron from an isolated gaseous atom so as to convert it into a gaseous Cation is Called ionization enthalpy.

The ionization enthalpies required to remove first, second, third etc. electron from an isolated gaseous atom are Called successive ionization enthalpies.

Factors Governing the ionization enthalpy.

a. nuclear charge – the ionization enthalpy increase with increase in nuclear charge.

b. Atomic size or radius – Ionization enthalpy decrease as the atomic size increase.

c. Penetration effect of the electron : Ionization enthalpy increases as the Penetration effect of the electron increases. $s > p > d > f$.

d. Shielding or screening effect of the inner shell electron – As the shielding or screening effect of the inner electrons increases the ionization enthalpy decreases.

in other words an increase in the number of electrons in the inner shell tends to decrease the ionization enthalpy.

e. Electronic Configuration :- more stable the electronic configuration, greater is the ionization enthalpy.

In Periodic table ionization enthalpy increase as we go from left to right in a Period and decrease as we go down in a group.

– Electron gain enthalpy :- It is defined as the energy released when a neutral isolated gaseous atom accepts an extra electron to form the gaseous negative ion

Depending upon the nature of the element the Process of adding an electron to the atom Can be either exothermic or endothermic, for majority of elements, energy is released when an electron is added to the atom, therefore, for such elements the electron gain enthalpy is negative. The electron gain enthalpy for halogens is heighly negative because they Can acquire the nearest stable nobal gas Configuration by accepting an extra electron. In Contrast nobal gases have large Positive electron gain enthalpy because the extra electron has to be Placed in the next higher Periniciple Quantum energy level

After the addition of one electron, the atom becomes negative charged and the Second electron is to be added to a negative charge ion. But the addition of second electron is opposed by electrostatic repulsion and hence the energy has to be supplied for the addition of second electron. thus the second electron gain enthalpy of an element is Positive.

— factors on which the electron gain enthalpy depends.

(a) Atomic size - As the size of the atom increases the force of attraction between the nucleus and the incoming electron decreases and hence the electron gain enthalpy become less negative.

(b) Nuclear charge :- As the nuclear charge increases the force of attraction between the nucleus and the incoming electron increases and hence the electron gain enthalpy is more negative.

(c) Electronic Configuration :- Elements having exactly half-filled or full-filled orbitals are very stable. As a result energy has to be supplied to add an electron. Hence their electron gain enthalpy have large Positive value.

— Variation of electron gain enthalpy

(a) Within a group :- In general the electron gain enthalpy become less negative as we move down a group.

The electron gain enthalpy of some of the elements of second Period (O and F are) less negative than the corresponding elements (S and Cl) of the third Period.

Hence amongest halogens Chlorine has the most negative electron gain enthalpy.

(b) Along a Period :- In general electron gain enthalpy becomes more and more negative from left to right in a Period.

Helogens have the most negative electron gain enthalpy.

— Electronegativity – electronegativity of an element is the tendency of its atom to attract the shared pair of electrons towards itself in a covalent bond. It is represented by χ

The electronegativity of any given element is not constant but depends upon the following factors.

(i) State of hybridization :- For example : a SP-hybridized Carbon is more electronegativity than a SP^2 or SP^3.

$$SP > SP^2 > SP^3.$$

(ii) Oxidation state :- As the oxidation state of the element increases the electronegativity increases.

$$Fe^{+3} > Fe^{+2}.$$

(iii) Nature of the substituents attached to the atom :-

Trends in groups and Periods :- The electronegativity value increases along a Period from left to right and decreases down a group. Hence F is most and Cs is least electronegativity elements.

— Diagonal relationship — Some elements of the second Period Show similarities with the elements of the third Period

Placed diagonally to each other though belonging to different group. (Li – Mg) (Be – Al) (B – Si) . this similarity in Properties of elements placed diagonally to each other is Called diagonal relationship.

The main reason for the behaviour of the first member of a Particular group of element in the S- and P- block Compared to the other member of the same group is.

(I) Small size (II) large charge/radius ratio
(III) high electronegativity (IV) absence of d- orbital.

— Bridge elements :- In the mendeleev's Periodic table, the elements of the third Period are also Called bridge elements Since the division of each main group into two subgroups A and B starts from these elements.