PERIODIC TABLE:CLASSIFICATION OF ELEMENTS

Periodic Classification :-

The arrangement of elements in such a way so that elements having similar properties reappear at a regular interval, is called periodic classification or periodic arrangement of elements

What is a Periodic Table?

The table consists of all elements in which elements are placed according to similar characteristics.

Introduction

- Matter around us is present in the form of elements, compounds and mixtures.
- Elements are substances containing atoms of only one type. Eg., Na, Mg, Au etc.
- There are 118 elements known to us. All these have different properties.
- To make the study of these elements easy, these elements have been divided into few groups in such a way that elements in the same group have similar properties.

HISTROY:CLASSIFICATION OF ELEMENTS

Dobereiner's Traids:

When elements were arranged in the order of increasing atomic masses, groups of three elements (known as **traids**), having similar chemical properties are obtained.

The atomic mass of the middle element of the triad was roughly the average of the atomic masses of the other two elements.

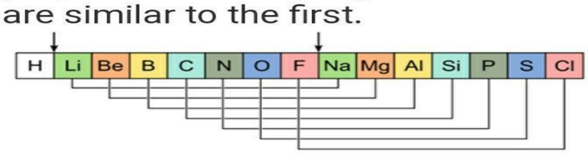
S. No.	Element	Atomic Mass	Mean of I and III
1.	I. Lithium II. Sodium III. Potassium	7 23 39	$\frac{7+39}{2}=23$
2.	I. Calcium II. Strontium III. Barium	40 88 137	$\frac{40+137}{2}=88.5$
3.	I. Chlorine II. Bromine III. Iodine	35.5 80 127	$\frac{35.5+127}{2}=81.25$

LIMITATIONS OF DOBEREINER'S TRIADS

- **It fails to arrange all the known elements in the form of triads, even having similar properties.**
- **He could identify only a few such triads and so the law could not gain importance.**
- **In the triad of Fe, Co, Ni, all the three elements have a nearly equal atomic mass and thus does not follow the above law**

Law of Octaves

According to Newland's law of octaves, when elements are arranged in the order of their increasing atomic mass, the properties of every eighth element are similar to the first.



Newlands' Octaves						
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	Cs

Limitations of Newlands Law of octaves

a) Newland law of octaves was applicable only upto calcium as after calcium every eighth element did not possess properties similar to that of the first.
b) Newland assumed that only 56 elements existed in nature. Several new elements were discovered, whose properties did not fit into the Law of Octaves.
c) In order to fit elements into his Table, Newlands adjusted two elements in the same slot, but also put some unlike elements under the same note. 15

Mendeleev's Periodic Law states that the physical and the chemical properties of the elements are a periodic function of their atomic masses.

Mendeleev's Periodic Table

Mendeleev arranged the elements known at that time in order of increasing atomic masses and this arrangement was called periodic table. Elements with similar characteristics were present in vertical columns called groups. The horizontal rows were known as periods.

Characteristics of the Periodic Table

The main characteristics of the periodic table are:

(1) In the periodic table, the elements are arranged in vertical columns called groups and horizontal rows known as periods.

(2) There are eight groups indicated by Roman Numerals as I, II, III, IV, V, VI, VII, VIII and the elements belonging to the first seven groups have been divided into sub-groups designated as A and B on the basis of similarities in properties.

(3) The elements that are present on the left hand side in each group constitute sub-group A while those on the right hand side form sub-group B. Group VIII consists of nine elements which are arranged in three triads.

(4) There are six periods (numbered from 1 to 6) or horizontal rows in the Mendeleev's periodic table. The periods 4, 5 and 6 are divided into two halves. The first half of the elements are placed in the upper left corners and the second half occupy lower right corners in each box.

5) Many gaps were left in the periodic table for the undiscovered elements which were identified later on and were placed at their respective positions.

6) Noble gases could be easily placed in a separate group called zero group (noble gas elements have zero valency) without disturbing the main periodic table.

Achievements of Mendeleev’s Periodic Table

Systematic study of the elements

Mendeleev for the first time arranged a very large number of the elements into groups and periods. This made the study of the elements quite systematic.

Prediction of new elements and their properties

Mendeleev laid more stress on similarity in properties rather on increasing atomic masses of the elements. So whenever a particular element did not fit in the arrangement, he left a gap in the periodic table. Thus, many gaps for the undiscovered elements were left in the periodic table by Mendeleev.

Correction of doubtful atomic masses

Mendeleev also corrected the atomic masses of certain elements with the help of their expected positions and properties.

Defects in the Mendeleev’s Periodic Table

Position of hydrogen

Hydrogen (Z = 1) is placed at the top of the alkali metal family because it resembles alkali metals in its properties.

For example: Both hydrogen and alkali metals form similar compounds with elements like oxygen, chlorine and sulphur etc.

Compounds of sodium: Na_2O, $NaCl$, Na_2S

Compounds of hydrogen: H_2O, HCl, H_2S

But at the same time, hydrogen also resembles halogens present in group VII A in many of its properties. Both are non-metals and also diatomic in nature. The compounds of both hydrogen and halogens with certain non-metals are of covalent nature.

Covalent compounds of hydrogen : CH_4, SiH_4, GeH_4

Covalent compounds of chlorine: CCl_4 , $SiCl_4$, $GeCl_4$

Anomalous positions of some elements

The elements in the Mendeleev’s Periodic table have been arranged in order of increasing atomic masses, but in some cases, the element with higher atomic mass precedes the element with lower atomic mass.

For example: Ar (Atomic mass =39.9) precedes K (Atomic mass= 39.1) and similarly Co (Atomic mass 58.9) has been placed ahead of Ni (Atomic mass=58.7). No justification has been given for such anomalous positions.

Position of isotopes

Isotopes of an element have different atomic masses but the same atomic number. Since the periodic table has been framed on the basis of increasing atomic masses of the elements, different positions must have been allotted to all the isotopes of a particular element.

For example: Three different positions should have been allotted to the isotopes of hydrogen with atomic masses 1, 2 and 3. But they have been assigned only one position.

No co-relation of elements in sub-groups

According to Mendeleev, the elements placed in the same group must resemble in their properties. But there is no similarity among the elements in the two sub-groups of a particular group.

For example: Li, Na and K present in group IA are quite different from Cu, Ag and Au which belong to group IB.

Different groups for similar elements

Elements with similar properties have been placed in different groups.

For example: Both copper and mercury resemble in many characteristics. But copper has been placed in group IB while mercury has been assigned position in group IlB

Cause of periodicity

No proper explanation has been offered to why the properties of the elements get repeated after gaps of atomic masses in a particular group.

Modern Periodic Law and Long-form of Periodic Table

The basis of Modern periodic law was provided by Mosley. The square root of the frequency of rays emitted from metal is proportional to the atomic number. In a neutral atom, atom, the atomic number is equal to the number of electrons and protons. Thus the basis of the classification of elements should be their atomic number.
Modern Periodic law states that the physical and chemical properties of the elements are a periodic function of their atomic number.

Modern Periodic Table

On the basis of this modern periodic law, Bohr proposed a long form of the periodic table the horizontal lines in a periodic table are called periods, and the vertical lines in a periodic table are called groups.

Groups

- There are 18 such groups in a periodic table.
- The elements in a group 1, 2,13-17 are called representative or normal elements.
- Elements in groups 3-12 are called transition elements.
- Elements that is in a group is known as family. It is usually named after the first element.

Examples:
Alkali Metals- Elements of group 1
Alkaline earth metals- Elements of group 2
Pnicogens- Elements of group 3
Chalcogens- Elements of group 16
Halogens- Elements of group 17
Noble gases- Elements of 18

Periods

- Horizontal columns or rows are known as periods. Seven Periods of the periodic table is the shortest period, short period, long period, longest period, and Incompleted period.
- Shortest Period- It is the first period. (1H 2He) contain 2 elements.
- Short Periods- - 2nd period (3Li 10Ne) contain 8 element, 3rd period (11Na 18Ar) also contains 8 elements
- Long Periods- 4th period (19K 36Kr) contain 18 element. The 5th period from (37Rb 54Xe) also contain 18 elements. These are known as long periods.

- Longest Periods- The 6th period (55Cs – 86Rn) contains 32 elements.
- Incomplete period or the 7th period is (87Fr –) incomplete and contains only 26 elements.

Blocks

Periodic table is divided into four main blocks (s,p,d and f) and depend upon the subshell to which valence electrons enter into:

- s-block- elements of group 1 and 2 constitute 2 compose the s-block.
- p-block- elements of group 13 to 18 compose of the p-block.
- d-block elements- elements of a periodic table in which the last electron occupies the d orbital, are called the d- block elements. These are also known as transition are elements. All these melements are metal except mercury which is a liquid element.
- f-block elements- f- block elements comprise of two horizontal rows in the bottom of the periodic table. There are a total of 28 f block elements in the periodic table. Lanthanides are elements from atomic number 58 to 71. These are also called rare earth elements Actinides are elements from 90 to 103, These are radioactive in nature.

Periodic Properties

Properties that show gradation on moving from left to right in a period or from top to bottom in a group are called periodic properties. Such properties are atomic size, ionization energy, electron affinity etc.

What is Atomic Size?

The distance between center of nucleus of an atom to the outermost shell is known a atomic size. It is not possible to determine the absolute value of atomic radii as:

- Since the orbital does not have defined boundaries, the accurate positions electrons in an atom cannot be determined.
- The distribution of electrons in a group of atoms in influenced by other atoms. Isolation of an individual atom is not possible.

Ionic Radius

- The distance between nucleus of ion and electrons in outermost shell, which can affect the ionic bond is known as ionic bond.

Atomic Radii and Ionic Radii

Atomic and Ionic Radii decrease on moving from left to right in a period. On moving from top to bottom in a group, atomic and ionic radii increase. This increase occurs with increase in the number of shells and an increase in the atomic number.

Ionization Enthalpy

- Atomic radius decrerases when we move from left to right in a period, When atomic radius or the size of the atom decreases, attractive force between the nucleus and outermost shell increases. Due to this along the period from left to right. Ionization energy increases while the ionization energy from top to bottom decreases.
- As the number of shell increases, increases in a group, the outmermost shell will be distant from the nucleus leading to less neutral effective charge.
- Some of the factors that affect ioionization energy are- Atomic Size, number of electrons in inner shell, nuclear charge, stable configuration, penetration effect.

Electron gain Enthalpy

- When we move left to right, across in a period, electron gain enthalpy starts becoming negative.
- When energy releases on gaining an electron, electron gain enthalpy is negative.
- When electron is gained and energy is provided to atom, it is electron gain enthalpy is positive.
- Elements are highly reactive on the two extreme sides in a periodic table, while noble gases and the elements that occupy the center position are least reactive.the elements that gain electrons to form an anion are located on the extreme right. These are known as Halogens. The elements that lose electrons to form cations are called cations and these are located to the extreme left. These are known as alkalis. While

moving across left to right in a period, the metallic property decreases while the non- metallic chcracteristics increases.

- Moving down in a group, the metallic and the non-metallic characteristics decreases.

Electronegativity

Electronegativity

The tendency of an atom to to strract electrons bonded pair towards itself is known as electronegativity.

- Electronegativity can be measured on different scales like Mulliken scale and Pauling scale. However, the most commonly used scale is Pauling Scale. According to this scale, the most electronegativ element is fluorine while least electronegative element is cesium.

Periodic Trend in Electronegative elements

- In a period, Electronegativity increases across left to right. This is due to the decrease in atomic size and and increase in nuclear charge.
- In a group, Electronegativity decreases from top to bottom. This is due to increase in atomic size and increase in nuclear charge. This increase in nuclear charge, is however prevailed over by the addition of a shell.

Most and Least Electronegative Element

- The most electronegative element is fluorine, its electronegative value is 3.98.
- The leaset electronegative element is cesium, its electronegative value is 0.79.

Factors that affect Electronegativity

Electronegativity of an element depend on various factors like atomic radii, nuclear charge, effect of substituent, oxidation state, hybridization.

- Atomic Radii- The greater the atomic radii, the less will be the electronegativity of an element. As the electrons are at a distance from the nucleus, the force of attraction will be less.
- Nuclear Charge- The greater the nuclear charge, the more will be the electronegativity of an element. An increase in nuclear charge will lead to a greater force of attraction between electrons.
- Oxidation State- When the positive oxidation state increases, electronegativity also increases.
- Hybridization- The more s- character is exhibited in hybrid orbital, the more will be the electronegativity.
- Substituent Effect- Electronegativity is also affected by the nature of substituent connected to the atom. The chemical behaviour of an atom is determined by the difference in electronegativity of an atom.

Valency

The number of electrons that are gained or lost or shared with atoms in order to form compounds is known as the valency of elements.

Valency for Group 1 and 2 elements- number of electrons in outermost shell

Valency for Group 13 to 14 elements- group number - 10

Valency for Group 15-18- 8 deducted by number of electrons in outermost shell.

*******---Extra Information**

General trends in periodic properties:

1. **Electronic configuration: So far we have already discussed the general electronic configuration of elements present in different groups, while discussing about various blocks. The general electronic configurations of all the elements in the same group are similar. The chemical properties of elements depend on the valence electronic configuration.**

2. **Atomic radii: It is defined as the distance from the centre of the nucleus to the outer most electron(s).**

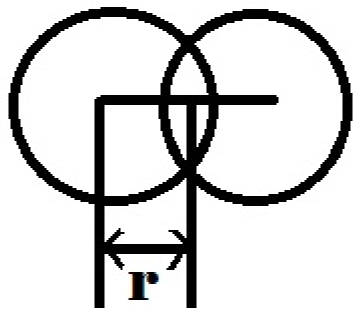
It is measured by electron diffraction method in angstrom (A°) or picometer (pm) unit.

The difficulties in measuring the exact atomic radius of an atom are that, except inert gas elements no other atoms are generally found in isolated or uncombined state. The exact position of the outer most electrons is uncertain according to Heisenberg's uncertainty principle. Furthermore the electron density of an atom is affected by the presence of neighboring atoms.

Despite the above limitations, we still need some practical approach to estimate the size of atoms. The hope is alive as the atoms pack up at certain definite distances in solids. This gives the idea about the approximate atomic size or radius of the atom. In this concern, depending upon whether the element is a metal or a nonmetal, three different types of atomic radii can be discussed.

i. Covalent radius:

a. Covalent Single Bond Radius For Homonuclear Molecules: **It is defined as one half of the distance between the nuclei of two covalently bonded atoms (bonded with a single bond) of the same element in a homonuclear molecule such as H2, F2, Cl2 etc.**



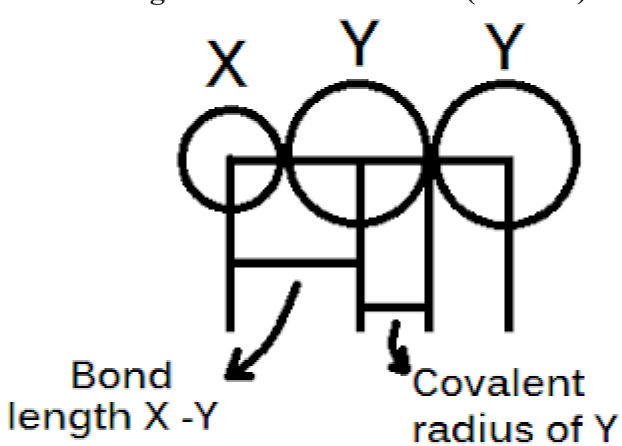
r = 1/2 (Internuclear distance between two bonded atoms)

r = 1/2 (bond length) , e.g. the internuclear distance between two chlorine atoms in Cl_2 molecule is 1.96 $A°$. Thus the covalent atomic radius of a chlorine atom is 1.96/2 = 0.98 $A°$.

***b*. Covalent Single Bond Radius For Heteronuclear Molecules where the electronegativity difference of corresponding bonded atoms is not so high:** **The covalent single bond radius of an atom X in a heteronuclear molecule is defined as the difference between the single bond length X - Y and the covalent radius of other single bonded atom, Y.**

Covalent radius of X in the single bond X - Y = Bond length of X -Y - Covalent radius of Y in X - Y

For example, the bond length of Si - C bond (d Si - C) is 193 pm and covalent radius of carbon atom (r C) is 77 pm. Thus the covalent single bond radius of Si = (d Si - C) - r C = 193 - 77 = 116 pm



c. Covalent Single Bond Radius For Heteronuclear Molecules where the electronegativity difference is high: **When there is a large difference in the electronegativity of two bonded atoms X and Y, the bond length will be shorter than expected and will have some ionic character of the bond. In this case the following relationship may be used:**

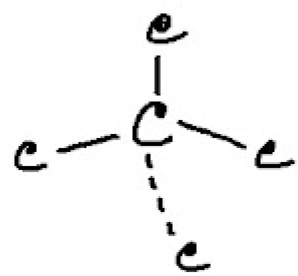
$d_{X-Y} = r_A + r_B - 0.09 (X_A - X_B)$, where d_{X-Y} is the bond length of X - Y and r_A and r_B are the covalent radius of A and B and X_A and the X_B are the electronegativities of A and B respectively.

Note: Like covalent single bond radius we can have also covalent multiple bond radius of C in C = C or of O in O = O using which the bond length of C = O can approximately be calculated.

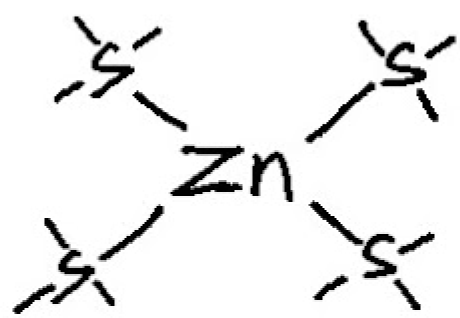
Covalent radii can further be studied as Tetrahedral covalent radii and Octahedral covalent radii.

d. Tetrahedral Covalent Radii: Crystals having arrangement of lattice points similar to either diamond or sphalerite (ZnS called Zinc blende having cubic structure) or wurzite (Sulphide of Zn having hexagonal structure) give rise to covalent radii.

In each of the arrangement where one atom is surrounded by four other atoms (similar or dissimilar atoms) tetrahedrally gives the covalent radius.



The central 'C' atom Surrounded by 4 atoms as in diamond



Tetrahedral arrangement in Sphalerite

Elements like C, Si, Ge, Sn have diamond like arrangement. All other elements which show tetrahedral arrangement are similar to either sphalerite (Cubic type structure) or wurzite (hexagonal structure).

If we consider the crystal of FeS_2 in which each sulphur atom is surrounded by three Fe and one S atom tetrahedrally, then we can find the S - S bond distance to be 2008 pm thus the tetrahedral covalent radii of S is 208 / 2 = 104 pm

Tetrahedral cov. radii of some elements (in pm)

Be (106)	B (88)	C (77)	N (70)	O (66)	F (64)
Mg (140)	Al (126)	Si (117)	P (110)	S (104)	Cl (99)
Cu (135)	Ag (152)	Zn (131)	Cd (148)	Hg (148)	

Comparision: Tetrahedral cov. radii & cov. single bond radii of 1st & 2nd row elements

Elements:	C	N	O	Si	P	S
Tetra. radii:	77	70	66	117	110	104
cov. single bond radii:	77	70	66	117	110	104