
ATOMIC STRUCTURE

ATOM:

Definition:

"Atom is a complex organization consisting of sub-atomic particles called Electrons, Protons and Neutrons."

Dalton's Atomic Theory:

This theory was given by British school teacher of chemistry.

This theory is based on the following points.

- i. All elements are made up of small indivisible, indestructible particles called atoms.
- ii. All atoms of a given element, are identical in all respects, having same size, mass and chemical properties. But the atoms of one element differ from the atoms of other element.
- iii. Compounds are formed when atoms of more than one element combine in a simple whole number ratio.
- iv. A chemical reaction is a rearrangement of atoms, but atoms themselves are not changed, this means that atoms are neither created nor destroyed in chemical reactions.

Defects in Dalton's Atomic Theory:

- i. According to Dalton's Atomic Theory, atoms of elements are indivisible and that no particle smaller than atom existed but the research confirmed that each atom consists of very small particles in the term of Electrons, Protons, Neutrons.
- ii. According to Dalton's Atomic Theory, different atoms of same element are identical in all aspects. But this is not true.
The discovery of isotopes proved that atoms (isotopes) of same element differ in mass i.e. C^{12} and C^{13} are two isotopes of Carbon. C^{12} has atomic mass 12 a.m.u whereas C^{13} has atomic mass 13 a.m.u. This difference of Neutrons in the two isotopes.

Modern Atomic Theory:

- i. Matter is composed of very tiny particles which possess all the properties of an element called Atom.
- ii. Atom is a complex organization consisting of sub-atomic particles called Electrons, Protons and Neutrons.
- iii. a) Atoms of an element are identical in size, shape and chemical properties but they may differ in their masses. Such atoms of an element are called Isotopes.
b) The atoms of one element are different from the atoms of other elements in all respect but the atomic masses of two or more elements may be same.
- iv. Compounds are formed when atoms of more than one element combine in a simple whole number ratio.
- v. A chemical reaction is a rearrangement of atoms, but atoms themselves are not changed, this means that atoms are neither created nor destroyed in chemical reactions.

Fundamental particles of an Atom:

Each atom consists of three subatomic particles called Electrons, Proton and Neutron. These subatomic particles are also called Fundamental particles.

DISCOVERY OF ELECTRONS OR CATHODE DISCHARGE TUBE

EXPERIMENT:

Electron is a fundamental particle of each atom having negative charge. This negative particle was discovered by a British physicist J.J Thomson.

Experiment:

This experiment consists of a glass tube of thick walls. The tube is fitted with two metal electrodes connected with negative and positive terminals of a high voltage battery. These plates are called Cathode and Anode respectively. This large tube consists of a small outlet tube connected with Vacuum pump. First of all this tube is filled with a gas at ordinary pressure. Now with the help of a vacuum pump the gas is evacuated such that the pressure of the gas inside the tube is reduced (Anode). This high voltage is slowly increased till a change in the tube is observed between the electrodes. Streaks of bluish lights having direction from cathode to anode are observed. It appears that these rays travel in straight lines from Cathode to Anode and a glow is observed on the tube toward Anode side where the rays strike.

To study the nature of charge (positive or negative) of the particle, these particles were passed through electric and magnetic field in the form of rays. It was observed that the particles travelling toward Anode were deviated from their path toward the positive plate of the magnetic field, so it is a clear indication that these particles are negatively charged called Electrons.

Same experiment was performed by changing the gas in the tube. It was observed that the nature of these particles remained same.

Same experiment was performed by changing the metal of electrodes, it was observed that the nature of particles remained same.

Important point to remember:

The negatively charged particles in the form of Cathode rays were not obtained from Cathode plate but these were originated by the discharge of gas particles between the two plates Cathode and Anode due to opposite charge. Since the direction was from Cathode to Anode these were called Cathode rays (actually are electrons).

Properties of Cathode Rays (Electrons):

- i. If an opaque object is placed in the path of cathode rays a shadow was observed which indicates that these particles travel in straight lines.
- ii. If a light paddle wheel is placed in the path of Cathode rays the wheel rotates which indicates that Cathode rays are material particles. The mass of each particle was found equal to $1/1837$ of the lightest Hydrogen atom (Isotope of Hydrogen having atomic mass equal to 1 a.m.u).
- iii. When these Cathode rays are allowed to strike glass material or some other materials, it is observed that these materials produce fluorescence (glow).
- iv. When these are deflected toward positive plate which indicates that these are negatively charged particles.
- v. The e/m ratio (charge/mass) ratio of Cathode particles is **. c/g** (coulomb/gram). The e/m ratio of electrons is also same. The Cathode particle of any other gas also carry the same e/m ratio.

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- vi. Since these Cathode particles are material particles and can produce mechanical pressure and are moving with certain velocity, so poses Kinetic energy.

DISCOVERY OF PROTONS:

Each atom is electrically neutral (having no charge), but each atom contains electrons inside it and those electrons are negatively charged particles, it means that positively charged particles are also present in each atom. These particles are called protons and each proton carry same quantity of positive charge as quantity of negative charge on each electron. Proton is also fundamental particle of all atoms.

Hydrogen (H) consists of one electron and one proton.

e.g. $\text{H} \rightarrow +$ Proton Electron

Experiment:

Goldstein a German physicist in 1886 performed an experiment to show the presence of material particles which are positive in nature.

He performed the same gas discharge tube experiment with the only difference was that the cathode was perforated.

It was observed that positive material particles crossed these perforations were collected behind the Cathode plate.

In 1897 J.J Thomson also confirmed the existence of these positively charged particles called protons. He also studied the properties of protons.

Properties of Positive rays:

- These rays travel in straight line in the direction from Anode to Cathode.
- When these rays were passed through electric field, it was observed that the particles were deflected toward negative plate, which indicates that these are positively charged particles.
- The e/m ratio of positive particle is much smaller than that of electrons.

Discovery of Neutrons:

In 1832 the British physicist James Chadwick discovered a third fundamental particle of atom with the help of artificial radioactivity. This particle is neutral in nature, having mass nearly equal to the mass of a proton.

Properties of Electron, Proton and Neutron:

ELECTRON	PROTON	NEUTRON
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1) Charge: The charge of Electron is negative. 2) Quantity of charge: 1.602×10^{-19} Coulomb Or 4.8×10^{-10} e. s. u. 3) Mass: Mass of electron is : 9.109390×10^{-31} kg	4) Charge: The charge of Proton is positive. 5) Quantity of charge: 1.602×10^{-19} Coulomb Or 4.8×10^{-10} e. s. u. 6) Mass: Mass of electron is : 1.672623×10^{-27} kg	7) Charge: Neutron is neutral. 8) Quantity of charge: No charge. 9) Mass: Mass of electron is : 9.109390×10^{-31} kg
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Important points to remember:

- The charge of Electron is simply considered as 1.602×10^{-19} Coulombs.
- Similarly the charge of proton is simply considered as 1.602×10^{-19} Coulombs.
- At some places the charge of Electron is written as -1.602×10^{-19} Coulomb. This is just an indication that it is negatively charged with the given value. This negative sign cannot be used for calculation purpose.
- Similarly at some places the charge of proton is written as $+1.602 \times 10^{-19}$ Coulombs to show magnitude of positive charge.
- The mass of electron is $1/1836$ part of the mass of proton. Similarly proton is 1836 times heavier than electron.

RADIOACTIVITY:

A phenomenon related to spontaneous disintegration of nucleus of an atom and emission of invisible radiations from the nucleus of an atom is called radioactivity.

Radioactive Substance:

"The substance which emit radiations spontaneously is called radioactive substance."

Examples of Radioactive substance:

Uranium (U), Thorium (Th) and Polonium (Po) are common examples of radioactive elements.

Type of Rays (, ,)::

In 1902 a British Physicist Ernest Rutherford performed an experiment to study the nature of radioactive rays.

A radioactive material was placed in the cavity of a thick Lead block. Radiations coming out of the cavity were passed through two plates of strong electric field. It was observed that these radiations split into three directions.

Positive charged particles:

- Were deflected toward negative plate.
- These positive charged particles are called Alpha (α) particles.

Negatively charged particles:

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- i. Were deflected towards positive plate.
 - ii. These negative charged particles are called Beta (β) particles.

Neutral rays:

- i. Were not deflected in any direction showing that these are neutral (having no charge).
- ii. These rays are called Gamma (γ) rays. These are not particle in nature.

Rutherford Atomic Model:

In 1911 Lord Rutherford successfully performed an experiment to study the structure of an atom.

Rutherford bombarded Alpha particle on a very thin Gold metal foil. He found the most of alpha particles passed through it without any deflection. Some of Alpha particles were deflected at large angles. Very few Alpha particles bounced back as shown in figure.

On the basis of this experiment Rutherford gave the following conclusions.

- i. Since most of the ' α ' particles passed un-deflected, so most of the portion of atom is empty.
- ii. Very few ' α ' particles bounced back, so the middle portion is the hardest portion of the atom and the entire positive charge of the atom is concentrated in that portion called nucleus.

Conclusions:

On the basis of the above experiment Rutherford concluded that nucleus of the atom of an element is positively charged and that nearly the entire mass of the atom is concentrated in that portion. This nucleus is located in the middle part of the atom.

Since atom as a whole is neutral (having a no charge) so there must be negative charge outside the nucleus. This negative charge is in the form of electrons revolving round the nucleus and the mass of electron is negligibly small as compared to the mass of the nucleus.

Nucleus not only consist of positively charged protons but it also contain neutral particles called Neutrons. The mass of Neutron is nearly equal to the mass of Proton.

Electrons revolve round the nucleus in various orbits called shells or energy levels.

Weaknesses or Defects in Rutherford's Atomic Model:

- i. According to classical electromagnetic theory a charged particle during its motion dissipates energy. If we apply this theory on electrons having negative charge it seems that during ~~continuous~~ revolving motion of electrons the energy is dissipated and due to loss of energy the electron must fall into the nucleus. ~~This is not true.~~
- ii. Since the electron revolves continuously, the energy dissipated must be continuous, so a continuous spectrum must be formed. But in actual practice line spectrums are obtained.

Bohr's Atomic Model:

In 1913 a Danish physicist gave a theory to solve the questions raised against Rutherford's atomic model.

Bohr's atomic model is based on the following points.

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- i. Electron is negatively charged particle but during its revolution it does not dissipate energy. So it will not fall in to the nucleus.
 - ii. When electron gains returns back in to its original energy level but it does not remain there and finally returns back to its original energy level. During downward jump of lines is called the line spectrum. The quantum energy is directly proportional to the frequency of radiation.
i.e. $\Delta E = E_2 - E_1 = h \nu$ where
 h = Planks constant.
 ν = Frequency of the radiation.

Atomic Number (Z):

"Atomic number is the number of protons in the nucleus of an atom." ➤

Atomic number is generally denoted by (Z).

- We know that the number of protons inside the nucleus of a neutral atom is equal to the total number of electrons outside the nucleus.
- All atoms are identified by their atomic numbers. ➤ No two elements can have same atomic number.

Consider the example of Carbon and Nitrogen:

Atomic number of Carbon is 6, but Atomic number of nitrogen is 7, so the properties of Carbon and Nitrogen are different. Because the number of protons of Carbon is 6 so the number of electrons is also 6. On the other hand the number of protons of Nitrogen is 7 so the number of electrons of Nitrogen is 7.

Note: Chemical properties of elements depend upon number of electrons of neutral atom.

Mass Number (A):

"Mass number is the total sum of protons and neutrons in the nucleus of an atom."

- All atoms (except ordinary Hydrogen atom) consist of both protons and neutrons inside its nucleus.
- Mass number (A) = Number of protons (Z) + Number of neutrons (N).
- $A = Z + N$.
- Number of neutrons = $A - Z$.

Consider the example of Sodium (Na):

Atomic number of Na = 11, and the mass number of Na = 23.

Therefore number of protons inside nucleus = 11.

And number of electrons outside nucleus = 11.

Number of Neutrons = $A - Z$.
 $= 23 - 11$.
 $= 12$.

ISOTOPES:

"Atoms of an element having same number of proton but different number of neutrons are called Isotopes." OR

"Isotopes are the atoms of same element having same atomic number but different atomic masses."

Consider the isotopes of chlorine (i) Cl-35 and (ii) Cl-37.

In Cl-35 the atomic number is 17, so the number of neutrons = $35 - 17 = 18$. In Cl-37 the atomic number is 17, so this chlorine also contains 17 protons and 17 electrons.

In Cl-37 the mass number is 37 so the number of Neutrons = $37 - 17 = 20$.

Note:

- Different isotopes of an element contain same number of electrons and same number of protons but different number of neutrons.
- Since chemical properties of an element depend upon the number of electrons in elements therefore two isotopes of an element have same properties.

OTHER EXAMPLE OF ISOTOPES

Isotopes of Hydrogen:

There are three isotopes of Hydrogen. i. Protium. ii.

Deuterium. iii. Tritium.

- Protium contains 1 electrons, 1 proton and $1 - 1 = 0$ means no neutron.
- Deuterium contains 1 electron, 1 proton and $2 - 1 = 1$ neutrons.
- Tritium contains 1 electron, 1 proton and $3 - 1 = 2$ neutrons.
- All these three isotopes have same chemical properties because they contain same number of electrons, but the difference is of mass due to difference in number of neutrons.

Applications of Isotopes:

- Usually isotopes are radioactive in nature except stable isotopes. So the radioactive isotopes are used as tracer (to trace many hidden things). Therefore a radio isotope helps in diagnosis of so many diseases.
- From a radioactive isotope radiations are emitted, which help in the cure of many diseases like cancer, in which these radiations are used for radiotherapy purpose.

ELECTRONIC CONFIGURATIONS:

Electron in an atom around revolve round its nucleus. These electrons revolve in different circular orbits called energy levels or shells.

The distribution of electrons on different energy levels is called electronic configuration.

These shells are designated as K, L, M, N, O and P orbits.

Each shell is also given a number 'n' as 1,2,3,4,5, and 6 respectively. On the basis of these numbers we can calculate the number of maximum electrons in these shells, with the help of a formula $2n^2$.

First 'K' shell contain $2n^2 = 2 \times 1^2 = 2$ electrons (maximum).

Second 'L' shell contain $2n^2 = 2 \times 2^2 = 8$ electrons (maximum). Third

'M' shell contain $2n^2 = 2 \times 3^2 = 18$ electrons (maximum).

EXERCISE

1. Fill in the blanks.

- i. **Rutherford atomic** model says that atom consists of small. Dense, positively charged nucleus which is surrounded by electrons, revolving around it.
- ii. Atomic number of sodium is **11**.
- iii. Number of proton + number of neutron is the **Mass Number** of an element.

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- iv. **Isotopes** are the atoms of the same elements, having same number of protons but different number of neutrons.
 - v. The number of isotopes of Hydrogen is **three**.
 - vi. **Atomic Number** is the number of positive charges in the nucleus of an atom.
 - vii. $A - Z$ indicates the number of **Neutrons** in the nucleus of an atom.
 - viii. Z = number of protons in the nucleus of an atom number of **electrons** in a neutral atom.

THE PERIODIC TABLE

Up till now 110 elements have been discovered out of these 92 are naturally occurring elements and the rest have been artificially prepared in the laboratories by nuclear reactions.

HISTORICAL DEVELOPMENT OF THE PERIODIC TABLE:

Periodic table was given after several stages of developments. These stages are discussed below.

AL-RAZI'S CLASSIFICATION:

- i. Al-Razi classified the elements into metals, non-metals and their derivatives.
- ii. The elements were divided into metals and non-metals based upon the difference in their physical and chemical properties.

DOBEREINER'S TRIADS:

In 1829, a German chemist Johan Wolfgang Dobereiner found out the relationship between atomic masses and properties of elements for the classification of elements. He arranged similar elements into groups of three. These families of three elements are known as DOBEREINER'S TRIADS.

LAW OR RULE OF DOBEREINER'S TRIADS:

"Central atom of each set of triad had an atomic mass almost equal to the arithmetical mean of the atomic masses of other two elements."

Dobereiner noticed that when the three elements in a triad were arranged in order of relative atomic masses, the relative atomic mass of the middle element was very close to the average of the other two elements.

For Example:

The approximate relative atomic mass of Chlorine and Iodine are 35.5 and 126.9 respectively. The average mass is 81.2 which is very close to the atomic mass of the middle element Br. i.e. 79.9.

$$(35.5 + 126.9) / 2 = 81.2$$

Similarly the relative atomic mass of Sodium 23.0 is the average of the relative atomic masses of Lithium (6.9) and Potassium (39.1).

$$\text{i.e. } (6.9 + 39.1) / 2 = 23.0$$

NEWLAND'S OCTAVE:

"In 1864 John Newland, an English chemist, reported his law of octaves. He arranged the elements in order of increasing atomic masses.

LAW OF OCTAVES:

"If the elements are arranged in ascending order of their atomic masses, then every eighth element starting from any point approximately has similar properties as of the first, like the eighth note in the octave of music."

Element	Li	Be	B	C	N	O	F
Atomic Mass	7	9	11	12	14	16	19
Element	Na	Mg	Al	Si	P	S	Cl
Atomic Mass	23	24	27	28	31	32	35.5
Element	K	Ca					
Atomic Mass	39	40					

From the above chart it is very clear that the properties of Li, Na and K are similar because these elements fall in eighth of the series. Similarly Be, Mg and Ca are similar in properties.

DISCREPANCIES OF NEWLAND'S OCTAVE:

- 'H' was not included in this sequence.
- This law was not applicable for large number of elements.

PERIODICITY:

"Repetition of similar properties after a regular interval or period is called PERIODICITY"

LOTHER MEYER'S CLASSIFICATION:

In December 1869 a German scientist Julius Luther Meyer arranged 56 elements which were discovered till then in a periodic table. Luther Meyer's classification based on atomic masses. He observed the relationship between physical properties (like volume) of the elements and their atomic masses therefore he arranged the elements on the basis of their atomic masses in nine vertical columns or groups from I to IX. The periodicity of physical properties becomes clear by comparing the atomic volumes of various elements.

ATOMIC VOLUME:

"ATOMIC VOLUME is the space occupied by gram atomic weight (1 mole) of atoms of an element in solid or liquid state. Number of atoms in a gram atom of elements is constant i.e. 6.02×10^{23} .

Luther Meyer calculated the volumes of eight elements.

$$\text{Atomic volume} = \text{Gram atomic weight} / \text{Density}$$

He plotted a graph between Atomic Volume of elements against their increasing atomic masses. The curve obtained consists of sharp peaks and broad minima.

He observed that the elements with similar positions on the curve. For instance, the highly reactive alkali metals (Li, Na, K, Rb, and Ca) occupy the peaks showing that these elements have largest atomic volumes. The regular spacing of the highest point confirms the idea of periodicity, suggested by Newland.

MENDELEEV'S PERIODIC TABLE:

In 1869, the Russian chemist, Dimitri Mendeleev, produced new ideas to support the theories, which Newlands, had suggested five years earlier. He arranged the elements in increasing order of their atomic masses.

THE PERIODIC LAW:

According to Mendeleev,

"The properties of element are the periodic function of their Atomic Weight."

Mendeleev arranged the elements in 12 horizontal rows called periods and 8 vertical columns called groups. The eight groups were further divided into subgroups.

SALIENT FEATURES OF THE TABLE:

- i. It has eight columns called groups and twelve horizontal rows called periods.
- ii. Elements in each vertical column have similar properties.
- iii. Vacant spaces for the elements not discovered until then. He proposed their names as Eka-Boron, Eka-Aluminum and Eka-Silicon.
- iv. The group number indicated the highest valence that can be attained by elements of that group.

ADVANTAGES OF MENDELEEV'S PERIODIC TABLE:

- i. It helped in systematic study of elements. For example the study of sodium helps to predict the properties of other alkali metals as potassium, rubidium, and cesium. It forcefully proved the concept of periodicity.
- ii. Prediction of new elements was made possible. Mendeleev predicted the physical and chemical properties of some element like Eka-Boron, Eka-Aluminum and Eka-Silicon. It helped in their discovery. Their properties were remarkably same as predicted by Mendeleev. They have been named as scandium (Eka-Boron), Gallium (Eka-Aluminum) and Germanium (Eka-Silicon).
- iii. Mendeleev's periodic table helped in correcting many doubtful atomic masses.
- iv. There was a regular gradation in the physical and chemical properties in a sub-group.
- v. The group number of an element indicates the highest valence state it can attain.

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- vi. Mendeleev left many spaces vacant in his periodic table for unknown elements and also predicted their properties.

Discrepancies in the Mendeleev's Periodic Table:

- i. There are three pairs of elements i.e. elements of higher atomic masses placed before elements of lower masses. i.e. a) Argon (40) placed before Potassium (39).
b) Cobalt (59.9) placed before Nickel (58.6).
c) Tellurium (127.5) placed before Iodine (126.9).
- ii. This table does not give any indication about the position of Isotopes. iii. Dissimilar elements placed in same group i.e. Alkali metals (Li, Na, K etc.) were placed with coinage metals (Cu, Ag, Au).
- iv. Mendeleev's table does not give an idea of structure of atoms.
- v. Lanthanides and Actinides have been assigned in same place in the periodic table which goes against periodic law.

- vi. The change in the atomic masses of two successive elements is not constant. Hence it is not possible to predict the number of missing elements by knowing the atomic masses of two known elements.

CONCLUSION:

On the basis of the above discussion we can conclude that the classification of the elements on the basis of atomic masses was not correct. In other words, atomic mass is not a fundamental property of the element.

Prediction of New Elements (The Missing Elements):

Mendeleev made some remarkable predictions about the undiscovered elements to fill the gaps in his table. Some examples are given below:

- i. Mendeleev predicted the properties of a metallic element to fill the gap below Aluminum and next to Zinc. When Gallium was discovered in 1876. It was found to confirm the almost accuracy of Mendeleev's predictions.
- ii. Mendeleev predicted the element he called Eka-Silicon (meaning below silicon) with its actual properties when it was found in 1886 and named Germanium (Ge).

MODERN PERIODIC TABLE:

MODERN PERIODIC LAW:

"Physical and chemical properties of elements are the periodic function of their Atomic numbers."

After the discovery of proton it was found that the properties of elements depend upon number of protons and their electronic configuration (electronic arrangement).

PERIODS:

"The horizontal rows in periodic table are called periods. There are seven periods in the modern periodic table."

1st PERIOD:

The first period consists of two elements. Hydrogen (H) and Helium (He). Hydrogen contains only one proton in its Nucleus, so its atomic no. is 1. In the same manner it contains 1 electron in its orbit due to this resembles to alkali metals which also have 1 electron in their outermost shell.

The next element is Helium. It has 2 electrons in the first shell. The electronic configuration of He is K=2. First shell cannot accommodate more than 2 electrons that is why Helium is placed in VIII or zero group. Helium shows extraordinary stability and inertness due to filled shell.

SECOND AND THIRD PERIOD:

Second and third period are called short periods. There are only eight elements present in these periods. Each element placed in respective group according to their electronic configuration. The elements included in these periods are:

2nd Period:

Li, Be, B, C, N, O and F.

3rd Period:

Na, Mg, Al, Si, P, S, Cl and Ar.

4th PERIOD:

Fourth period is called long period. They include eighteen elements, out of eighteen elements eight are called normal element and the remaining ten are called Transition elements.

Normal elements: K, Ca, Ga, Ge, As, Se, Br and Kr.

Transition elements: Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn.

5th PERIOD:

The fifth period is called a long period. It consists of eight normal elements and ten transition elements.

Normal elements: Rb, Sr, In, Sn, Sb, Te, I and Xe.

Transition elements: Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag and Cl.

6th PERIOD:

The sixth period is the longest period and it consists of 32 elements. It consists of 8 normal elements, 10 outer transition and 14 called Lanthanides or Rare Earth Metals.

Normal elements: Cs, Ba, Ti, Pb, Bi, Po, At and Rn.

Outer transition: La, Hf, Ta, W, Re, Os, Ir, Pt, Au and Hg.

Inner transition: Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu.

7th PERIOD:

Seventh period is incomplete. It contains two elements as normal elements, ten outer transition element and fourteen inner are called actinides. The actinides are radioactive elements. Some of them have been proposed artificially.

Normal elements: Fr and Ra.

Outer transition: Ac, Unq, Unp, Unh, Uns, Une, Uno and Unu.

Inner transition: Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, E, Fm, Md and No.

GROUPS:

"The vertical columns in the periodic table are called groups."

Element with similar outer electronic configuration show similar properties and are placed in same group.

Periodic table consists of eight Groups. They are further sub divided in to two sub-groups. Normal elements are kept in "A" group and transition elements in sub group "B",

GROUP I-A THE ALKALI METALS: (LITHIUM FAMILY)

- i. The alkali metals, lithium, sodium, potassium, rubidium, cesium and francium are light metals.
- ii. They are very reactive chemically and are strongly mono electro positive elements.
- iii. Ionization potential decrease gradually downward in the group.
- iv. All these metals contain only one electron in their outermost shells.
- v. They form ionic bond by the loss of valence electron.
- vi. Alkali means "ashes". This is an Arabic word. Compound of these metals were obtained from wood ashes and it is also because they form water and soluble bases (Alkalies).

GROUP II-A THE ALKALINE EARTH METALS:

- i. Beryllium, magnesium, calcium, strontium, barium and radium are included in Group IIA the alkaline earth metals.
- ii. They are moderately reactive metals, harder and less volatile than the alkali metals.
- iii. These elements are found as silicate minerals and their oxides and hydroxides are strongly basic. Therefore these elements are called Alkaline Earth Metals.
- iv. They contain two electron in their outer most shell.
- v. Metallic characters increase downward in the group.

GROUP III-A THE BORON FAMILY:

- i. Boron, aluminum, gallium, indium and thallium are included in this group.
- ii. Boron is metalloid, while the other members of this group are metals.
- iii. These elements are quite reactive chemically and are highly electropositive.
- iv. They have three electrons in their outermost shell.
- v. Metallic characters increase downward in the group.
- vi. The elements of this group shown tendency to form covalent bond like non-metals due to small size, high charge and large value of ionization potentials.
- vii. (Metalloid = Elements which have some properties of metals and some properties of non-metals).

GROUP IV-A CARBON FAMILY:

- i. Carbon, silicon, germanium, tin and lead are present in this group. ii. They show intermediate characteristics.
- iii. It is the middle group of periodic table forming the link between the more electropositive. And electronegative elements. Elements of group I and II and more electronegative elements of group V to VII.
- iv. They contain same electronic configuration and have four electrons in their outermost shell.
- v. Electronegativity decreases from carbon to lead.
- vi. Carbon and silicon being more electronegative are non-metals and form covalent bonds only by sharing their four valence electrons.
- vii. Tin and lead are electropositive. They are typical metals and form ionic bonds by losing electrons in their valence shell.
- viii. Allotropes of C and Sn elements are found in this group.

GROUP V-A THE NITROGEN FAMILY:

- i. Nitrogen, phosphorus, arsenic, antimony and bismuth are included in this group. Nitrogen and phosphorous are non-metals. Arsenic and antimony are metalloids and bismuth is weakly metallic.
- ii. They have five electrons in their outer most shell and require three electrons to complete their octet.
- iii. The tendency of forming covalent bonds decrease from nitrogen to bismuth.
- iv. Nitrogen exists as diatomic molecules (N₂) and forms number of oxides NO, N₂O, NO₂, N₂O₄ and N₂O₅.
- v. Due to small atomic size and large ionization potential, nitrogen has a tendency to accept three electrons to form Nitride N⁻³.

- vi. Bismuth forms ionic bond only and forms " Bi^{3+} ".
- vii. Phosphorus exists as P_4 molecule.
- viii. The ionization potential are high, hence nitrogen and phosphorous are distinctly electronegative.
- ix. Except nitrogen all exist in more than one allotropic forms. The group displays a remarkable number of allotropes of its member. Note: (Different forms of an atom having same chemical properties and different physical properties are called Allotropes and the phenomenon related to its called Autotropy).

GROUP VI-A THE OXYGEN FAMILY:

- i. Oxygen, sulphur, selenium, tellurium and polonium are the members of group VI-A.
- ii. Oxygen and sulphur are non-metals, whereas tellurium and selenium are close to metalloids and basic metallic properties are shown only by polonium.
- iii. The metallic character, ionic and basic nature increase from oxygen to polonium.
- iv. Oxygen is a gas other elements are solids.
- v. They have six electron in their outer most shell.
- vi. All the element exhibit property of Allotropy e.g. Ozone O_3 and O_2 .
- vii. They form ionic compounds by the gain of two electrons and form covalent by sharing two electrons e.g. H-O-H , H-S-H , O=C=O , Cl-S-S-Cl .
- viii. The electro negativity values of these elements are very high and decrease down the group.

GROUP VII-A THE HALOGEN FAMILY:

- i. Fluorine, chlorine, bromine, iodine and astatine are included in the Halogen group (Halogen = salt former).
- ii. They are very active non-metals and are very much like in their chemical properties.
- iii. They contain seven electrons in their outermost shell and require only one electron to attain stability.
- iv. They form covalent compounds as well as ionic compounds e.g. NaCl (ionic), HCl (covalent).
- v. Halogens are highly electronegative elements and their electronegativity decreases down the group from fluorine to iodine.
- vi. Fluorine and chlorine are gases and rest of them are solid elements except bromine which is liquid.
- vii. They easily accept an electron to form halide ions.
- viii. They all are found as diatomic molecule. They cannot exist in Free State because of their extreme activity.

GROUP VIII-(ZERO) THE NOBLE GASES:

- i. Helium, neon, argon, krypton, xenon and radon are the members of group VIII.
- ii. They are also called Noble gases, Inert gases or "Zero Group".
- iii. They are also mono atomic and low boiling gases.
- iv. Their outer most shell is complete and these all elements are stable and are mostly chemically inactive and have no tendency to form compounds.
- v. All the noble gases except radon are normally present in atmosphere i.e. argon present 1% in atmosphere by volume.
- vi. By the process of liquefaction these gases can be changed in to liquid.

TRANSITION ELEMENTS:

- i. Elements in groups IB, IIB through VIIB are known as Transition elements.
- ii. They include the elements scandium, yttrium, lanthanum and actinium and the two rare earth series of elements lanthanides and actinides series ('f' block elements).
- iii. They are also called "d" block elements. They have incomplete inner electron shells and are characterized by their variable valences and show similar behaviors.
- iv. All transition elements are metals, in which the bonds between the atoms are very strong and they have high melting points.
- v. They have an outstanding ability to form complex ion by coordination.
- vi. The compounds are formed by coordinate covalent bonds.

THE POSITION OF METALS, NON-METALS AND METALLOIDS IN THE PERIODIC TABLE:

Position of metals:

- i. Group IA (except hydrogen) IIA, IIIA, IB, IIB, the transition elements including lanthanides and actinide series are all classified as metals. ii. Some elements of group IV and V-A are metals e.g. Pb, Bi etc.
- iii. Metallic properties are pronounced as lower left hand corner of the periodic table.

Position of metals:

- i. They are electro positive elements i.e. they lose electron to form Cat ions.
- ii. They form basic oxides. iii. They have luster (shine). iv. They are malleable (i.e. can be spread out in to sheets). v. They are ductile (i.e. they can be drawn in to wires).
- vi. They are good conductors of heat and electricity.

Position of non-metals:

- i. Majority of elements of P-block in groups III-A, VI-A, V-A, VII-A and VIII are metals. ii. Non-metallic properties are pronounced in the upper right hand corner of the periodic table.

Properties of non-metals:

- i. They are electronegative elements i.e. they gain electrons to form anions (negative ions).
- ii. They form acidic oxides.
- iii. They are bad conductors of heat and electricity.
- iv. Most of them are gases.

METALLOIDS:

"The elements which show the properties of both metals as well as nonmetals are called Metalloids."

Their oxides are amphoteric i.e. have basic as well as acidic nature.

Some examples of Metalloids.

- i. Boron (B) in group III-A.

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- ii. Silicon (Si) and Germanium (Ge) in group IV-A. iii. Arsenic (As) and Antimony (Sb) in group V-A. iv. Tellurium (Te) and Polonium (Po) in group VI-A. v. Astatine of group VII-A.

PERIODIC TRENDS:

There are various trends in a group or family of elements given below:

- i. **Similar Properties:**
The elements show similar properties due to their similar electronic configuration.
- ii. **Regular Gradation:**
A regular gradation in physical and chemical properties of elements in a group are observed due to gradual change in their electro negativities and atomic sizes.
- iii. **Size of Atom:**
The first member of each group shows slightly different behavior from other members of that group. It is due to abnormally high electronegativity and small size of atom or due to remarkable difference in Atomic number.
- iv. **Metallic Character:**
The metallic character or electro positivity of metals of 1st, 2nd and 3rd group increases with increasing atomic number downward in the group.
- v. **Electro negativities:**
The electro negativities of elements decrease with increasing atomic numbers. Thus among halogens, fluorine is the most electronegative and iodine the least.

APPLICATION OF PERIODIC TABLE:

Classification of periodic table in to periods and groups is very useful in the study of chemistry, as properties of elements are predictable on the basis of their position on the periodic table.

- Suggestion for further research is available.
- Prediction of new elements has been possible.
- Prediction of chemical characteristics of element is possible.
- Reactivity's of elements can be visualized.
- Atomic structure is cleared.
- Atomic number, mass etc. of atoms and such other basic informations are obtained from table.

SOME PERIODIC PROPERTIES OF ATOMS:

- i. Atomic Radius. ii. Ionization Energy. iii. Electron Affinity. iv. Electronegativity.

i. **ATOMIC RADIUS:**

"Half of the distance between the nuclei of two similar adjacent atoms is called Atomic Radius."

Unit of Measurement:

Atomic radius is measured in Angstrom Unit. It is represented by A.U.

Factors on which Atomic Radius depends:

Atomic radius depends up on following.

- a. Number of shells.
- b. Nuclear charge.

Periodic Trend:**a. Trend in Groups:**

Atomic radius increases downward in a group due to addition of new shell.

b. Trends in Periods:

Atomic radius decreases left to right in a period due to increase in a nuclear charge by the addition of proton in nucleus. Nuclear charge pulls the orbiting electron with more force which reduces the size of atom.

ii. IONIZATION ENERGY (I.E OR I.P):

"The minimum amount of energy required to remove an electron from an isolated gaseous atom in its ground state is called ionization energy or ionization potential."

UNIT:

It is measured in kilo joule/mole (KJ/mol) or electron volt per atom (ev/atom).

Factors on which I.E depends:

The ionization energy depends up on atomic size and nuclear charge. The higher the I.E the more difficult is to remove an electron.

Trends in Group:

Ionization energy decreases downward in a group as the addition of a new shell decreases the hold of nucleus on valence shell.

Trends in a Period:

I.E increases left to right in a period, due to addition of proton in the nucleus increase the nuclear charge which increases the force of attraction on electron.

iii. ELECTRON AFFINITY:

"The energy change that occur when an electron is gained by an atom in the gaseous state is called Electron Affinity."

Unit:

It is measured in KJ/mol or in e.v per atom. EA for 1st electron is negative i.e. Energy is released but for second electron EA is positive because energy has to be further added to overcome repulsion between negative ion and electron.

Factor on which Electron Affinity depends:

It depends up on the Atomic size and nuclear charge.

Trend in a Group:

Electron affinity decreases downward in a group because the addition of a new shell to each atom decreases its force of attraction.

Trend in a Period:

Left to right in a period E-A increases due to the increase in nuclear charge. Fluorine (F) has abnormally low electron affinity because due to its very small atomic size it does not accept electron easily.

iv. ELECTRONEGATIVITY:

"Electronegativity is the relative tendency of an atom in a molecule to attract a shared pair of electrons toward itself."

It is denoted by a number and has no unit.

Linus Pauling calculated the electro negativities of different elements taking fluorine as standard with its E.N = 4.

Trend in a Group:

E.N increases downward in a group as the power of nucleus to attract electron decreases due to increase in atomic sizes by the addition of an extra shell.

Trends in a Period:

E.N increases from left to right in a period due to increase in nuclear charge variation of electronegativity with atomic number and the periodicity in it.

EXERCISE

1. FILL IN THE BLANKS:

- i. The rule of triad was introduced by **John Wolfgang Dobereiner** ii.
The repetition of properties after regular intervals is called **Periodicity** iii.
The longer period is **6** period and contains total **32** elements.
- iv. The elements that contain both metallic and non-metallic characteristics are called **Metalloids**
- v. The long form of periodic table contains **8** groups and **7** periods.
- vi. According to Mendeleev the properties of the elements are the periodic functions of their **Atomic mass.**