Science and Technology

Part 1

Chapter 2: Periodic Classification of Elements

- Today 118 elements are known to the scientific world.
- Elements were classified into the groups of metals and nonmetals and metalloids.

Dobereiner's Triads:

- In the year 1817 a German scientist Dobereiner suggested that properties of elements are related to their atomic masses. He made groups of three elements each, having similar chemical properties and called them triads.

- He arranged the three elements in a triad in an increasing order of atomic mass and showed that the atomic mass of the middle element was approximately equal to the mean of the atomic masses of the other two elements.

- However, all the known elements could not be classified into the Dobereiner's triads.

Sr. No.	Triad	Element -1 Actual atomic mass(a)	Element - 2		Element - 3 Actual atomic mass (c)
			Mean = $\frac{a+c}{2}$	Actual atomic mass	
1	Li, Na, K	Lithium (Li) 6.9	Sodium $\frac{6.9 + 39.1}{2} = 23.0$	(Na) 23.0	Potassium (K) 39.1
2	Ca, Sr, Ba	Calcium (Ca) 40.1	Strontium $\frac{40.1+ 137.3}{2} = 88.7$	(Sr) 87.6	Barium (Ba) 137.3
3	Cl, Br, I	Chlorine (Cl) 35.5	Bromine $\frac{35.5 + 126.9}{2} = 81.2$	(Br) 79.9	Iodine (I) 126.9

In the year 1866 Newlands arranged the elements known at that time in an increasing order of their atomic masses. It started with the lightest element hydrogen and ended up with thorium. He found that every eighth element had properties similar to those of the first. For example, sodium is the eighth element from lithium and both have similar properties Newlands compared this similarity with the octaves in music. He called the similarity observed in the eighth and the first element as the **Law of octaves.**

Law of octaves.

Musical Note	Do (Sa)	Re (Re)	Mi (Ga)	Fa (Ma)	Sol (Pa)	La (Dha)	Ti (Ni)
Elements	H F Cl Co &Ni Br	Li Na K Cu Rb	Be Mg Ca Zn Sr	B Al Cr Y Ce & La	C Si Ti In Zr	N P Mn As	O S Fe Se

Many limitations were found in Newlands' octaves. This law was found to be applicable only upto calcium.

Mendeleev's Periodic table:

- The Russian scientist Dmitri Mendeleev developed the periodic table of elements during the period 1869 to 1872 A.D.

- Mendeleev considered the fundamental property of elements, namely, the atomic mass, as standard and arranged 63 elements known at that time in an increasing order of their atomic masses.

On the basis of this finding Mendeleev stated the following periodic law. Properties of elements are periodic function of their atomic masses.

Merits of Mendeleev's periodic table:

1. Atomic masses of some elements were revised so as to give them proper place in the periodic table in accordance with their properties.

2. Mendeleev kept vacant places in the periodic table for elements not discovered till then. Three of these unknown elements were given the names Eka-boron, Eka-aluminium and Eka-silicon from the known neighbours and their atomic masses were indicated as 44, 68 and 72, respectively.
Later on these elements were discovered and named as scandium (Sc), gallium (Ga) and germanium (Ge) respectively.

3. There was no place reserved for noble gases in Mendeleev's original periodic table.

Demerits of Mendeleev's periodic table:

1. The whole number atomic mass of the elements cobalt (Co) and nickel (Ni) is the same. Therefore, there was an ambiguity regarding their sequence in Mendeleev's periodic table. As isotopes have the same chemical properties but different atomic masses, a challenge was posed in placing them in Mendeleev's periodic table.

3. When elements are arranged in an increasing order of atomic masses, the rise in atomic mass does not appear to be uniform. It was not possible, therefore, to predict how many elements could be discovered between two heavy elements.

4. Position of hydrogen: Hydrogen shows similarity with halogens (group VII). In the same way, there is a similarity in the chemical properties of hydrogen and alkali metals (group I).
It cannot be decided whether the correct position of hydrogen is in the group of alkali metals (group I) or in the group of halogens (group VII).

Modern Periodic Law:
In 1913 A.D. the English scientist Henry Moseley demonstrated, with the help of the experiments done using X-ray tube. This revealed that 'atomic number' is a more fundamental property of an element than its atomic mass. Accordingly, the statement of the modern periodic law was stated as follows:
'Properties of elements are a periodic function of their atomic numbers.'

Modern periodic table (long form of the periodic table):
The modern periodic table is also called the long form of the periodic table. In the modern periodic table, the elements are arranged in accordance with their atomic number. However, the ambiguity about the position of hydrogen is not removed even in the modern periodic table.

Structure of the Modern Periodic Table:

- The modern periodic table contains seven horizontal rows called the periods 1 to 7.
- The eighteen vertical columns in this table are the groups 1 to 18.
- Apart from these seven rows, two rows are shown separately at the bottom of the periodic table. These are called lanthanide series and actinide series, respectively.
- There are 118 boxes in the periodic table including the two series. It means that there are 118 places for elements in the modern periodic table. Very recently formation of a few elements was established experimentally and thereby the modern periodic table is now completely filled.
- All the 118 elements are now discovered.
- The entire periodic table is divided into four blocks viz, s-block, p-block, d-block and f-block. The s-block contains the groups 1 and 2.
- The groups 13 to 18 constitute the p-block.
- The groups 3 to 12 constitute the d-block, while the lanthanide and actinide series at the bottom form the f-block. The d-block elements are called transition elements.
- A zig-zag line can be drawn in the p-block of the periodic table.

- The three traditional types of elements can be clearly shown in the modern periodic table with the help of this zig-zag line.
- The metalloid elements lie along the border of this zig-zag line. All the metals lie on the left side of the zig-zag line while all the nonmetals lie on the right side.

Modern periodic Table and electronic Configuration of Elements:

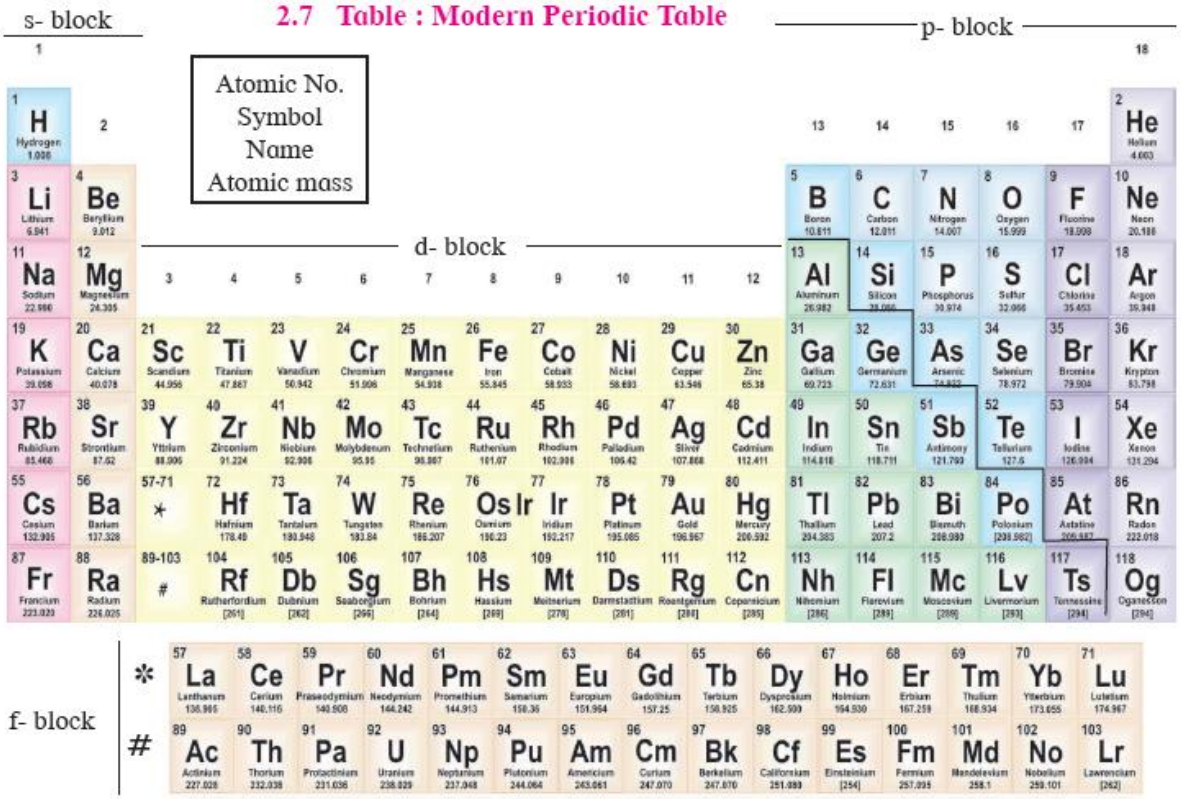
- Within a period, the neighbouring elements differ slightly in their properties while distant elements differ widely in their properties.
- Elements in the same group show similarity and gradation in their properties.
- It is the electronic configuration of an element which decides the group and the period in which it is to be placed.
- The number of valence electrons in all these elements from the group 1, that is, the family of alkali metals, is the same.
- Similarly, if you look at from any other group, you will find the number of their valence electrons to be the same. For example, the elements beryllium (Be), magnesium (Mg) and calcium (Ca) belong to the group 2, that is, the family of alkaline earth metals. There are two electrons in their outermost shell.
- Similarly, there are seven electrons in the outermost shell of the elements such as fluorine (F) and chlorine (Cl) from the group 17, that is, the family of halogens.
- While going from top to bottom within any group, one electronic shell gets added at a time.
- From this we can say that the electronic configuration of the outermost shell is characteristic of a particular group.
- However, as we go down a group, the number of shells goes on increasing.

Note: Uranium has atomic number 92. All the elements beyond uranium (with atomic numbers 93 to 118) are manmade. All these elements are radioactive and unstable, and have a very short life.

In the modern periodic table.....

1. Elements are arranged in an increasing order of their atomic numbers.
2. Vertical columns are called groups. There are 18 groups. The chemical properties of the elements in the same group show similarity and gradation.
3. Horizontal rows are called periods. There are in all 7 periods. The properties of elements change slowly from one end to the other in a period.

Periods and electronic configuration:



Periods and electronic configuration:

- The elements with the same number of shells occupied by electrons belong to the same period.
- The elements in the second period, namely Li, Be, B, C, N, O, and Ne have electrons in the two shells, K and L.
- The elements in the third period, namely Na, Mg, Al, Si, P, S, Cl and Ar have electrons in the three shells; K, L and M.
- The number of elements in the first three periods is determined by the electron capacity of the shells and the law of electron octet.
- As per the electron holding capacity of shells 2 elements are present in the first period and 8 elements in the second period.
- The third period also contains only eight elements due to the law of electron octet.
- The chemical reactivity of an element is determined by the number of valence electrons in it and the shell number of the valence shell.

Shell	n	$2n^2$	Electron Capacity
K	1	$2x1^2$	2
L	2	$2x2^2$	8
M	3	$2x3^2$	18
N	4	$2x4^2$	32

Periodic trends in the modern periodic table:
When the properties of elements in a period or a group of the modern periodic table are compared, certain regularity is observed in their variations. It is called the periodic trends in the modern periodic table.

Valency:
The valency of an element is determined by the number of electrons present in the outermost shell of its atoms, that is, the valence electrons.

Symbol	$_{19}K$
Electronic configuration	2, 8, 8, 1
Valency	1

Atomic size

- The size/volume is a fundamental property of matter. The size of an atom is indicated by its radius.
- Atomic radius is the distance between the nucleus of the atom and its outermost shell.

Atomic radius is expressed in the unit picometer (pm) which is smaller than nanometer ($1\ pm = 10^{-12}\ m$).

Some elements and their atomic radii are given here.

Element	:	O	B	C	N	Be	Li
Atomic radius (pm)	:	66	88	77	74	111	152

- Atomic radius goes on decreasing while going from left to right within a period. The reason behind this is as follows.
- While going from left to right within a period, the atomic number increases one by one, meaning the positive charge on the nucleus increases by one unit at a time.
- However, the additional electron gets added to the same outermost shell.
- Due to the increased nuclear charge the electrons are pulled towards the nucleus to a greater extent and thereby the size of the atom decreases.
- While going down a group the atomic size goes on increasing. This is because while going down a group a new shell is added. Therefore, the distance between the outermost electron and the nucleus goes on increasing. As a result of this the atomic size increases in spite of the increased nuclear charge.

Metallic- Nonmetallic Character:

- It is seen that the metallic elements like sodium, magnesium are towards the left. The nonmetallic elements such as Sulphur, chlorine are towards the right. The metalloid element silicon lies in between these two types. A similar pattern is also observed in the other periods.
- It is seen that the zig- zag line separates the metals from nonmetals in the periodic table.

- Elements appear to have arranged in such a way that metals are on left side of this line, nonmetals on the right side and metalloids are along the border of this line.
- The cation in them is formed from a metal while the anion from a nonmetal. From this it is understood that metal atoms have a tendency to form a cation by losing its valence electron, this property is called electropositivity of an element.
- On the other hand, an atom of a nonmetal has a tendency to form an anion by accepting electrons from outside into its valence shell.
- Metals have a tendency to lose the valence electrons to form cations having a stable noble gas configuration. This tendency of an element called electropositivity is the metallic character of that element.
- The metallic character of elements increases while going down the group. While going from left to right within a period the outermost shell remains the same.
- However, the positive charge on the nucleus goes on increasing while the atomic radius goes on decreasing and thus the effective nuclear charge goes on increasing.
- As a result of this the tendency of atom to lose valence electrons decreases within a period from left to right.
- The two factors namely, the increasing nuclear charge and decreasing atomic radius as we go from left to right within a period, are responsible for increasing the effective nuclear charge. Therefore, the valence electrons are held with greater and greater attractive force. This is called **electronegativity** of an atom.
- The tendency of an element to form anion or the electronegativity is the nonmetallic character of an element.

Gradation in Halogen Family:

- The group 17 contains the members of the halogen family.
- All of them have the general formula X_2.
- A gradation is observed in their physical state down the group.
- Thus, fluorine (F_2) and chlorine (Cl_2) are gases, bromine (Br_2) is a liquid while iodine (I_2) is a solid.
