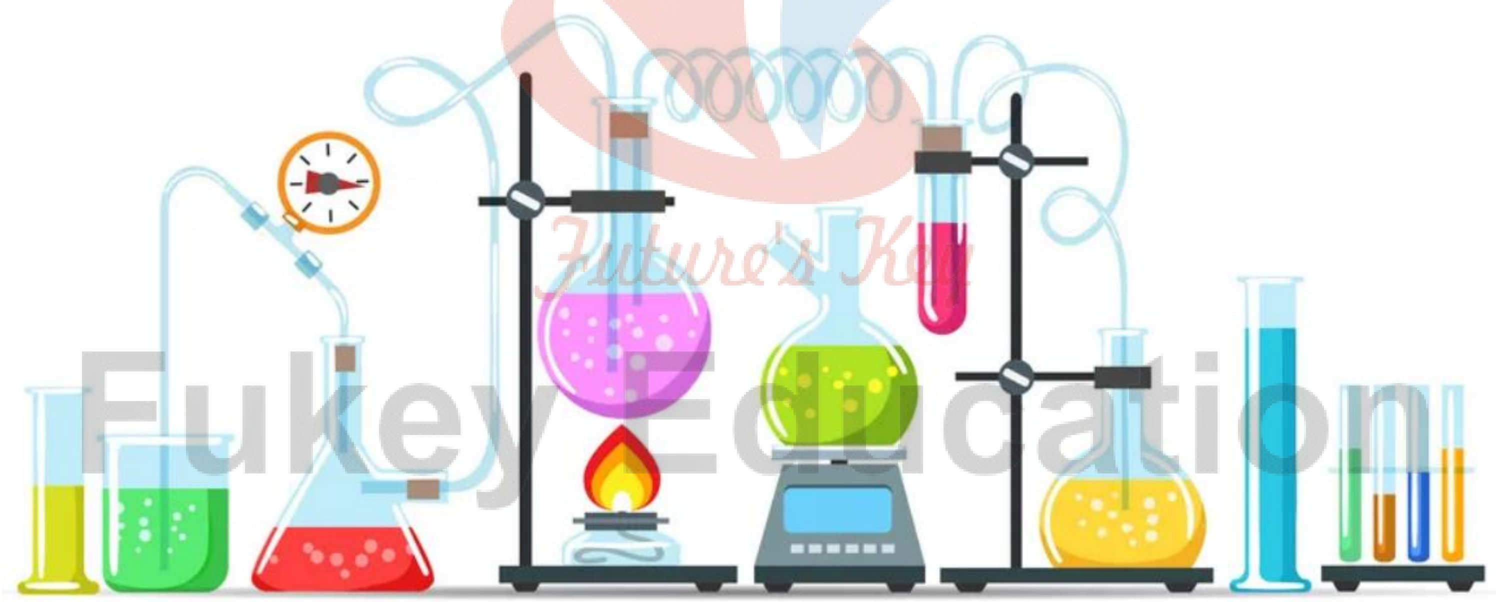
# CHEMISTRY

## CHAPTER 3: CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES



# CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES

## Introduction:

Classification of elements was proposed in order to study all the elements in a systematic manner. In this Unit, we shall study the development of the Periodic Law and the Periodic Table. Mendeleev's Periodic Table was based on atomic masses. Modern Periodic Table arranges the elements in the order of their atomic numbers in seven horizontal rows (periods) and eighteen vertical columns (groups or families).

## Why Do We Need Classification?

Elements are the basic units of all types of matter. At present, 118 elements are known. With such a large number of elements, it is very difficult to study individually the chemistry of all these elements and their number of compounds. So to make the study of chemistry simpler, scientists searched for a systematic way to organise their knowledge by classifying the elements. Main aim behind this classification was to keep the elements of same properties together, so that by studying one element out of that group, we can have general idea about the properties of all the elements in that group.

## Periodic Table

Periodic table may be defined as the tabular arrangement of elements in such a way that the elements having same properties are kept together.

## Dobereiner's Triads Law

1st attempt towards the classification of elements was made by Johann W. Dobereiner in 1817. He arranged elements in the groups of three and in such a way that the atomic weight of middle element was equal or nearly equal to the average of atomic weights of other two elements.

| | ELEMENTS | SYMBOL | ATOMIC MASS |
|---|---|---|---|
| 1 | Lithium | Li | 6.9 |
| | Sodium | Na | 23 |

| | | | |
|---|---|---|---|
| | Potassium | K | 39 |
| 2 | Calcium | Ca | 40.1 |
| | Strontium | Sr | 87.6 |
| | Barium | Ba | 137.3 |
| 3 | Chlorine | Cl | 35.5 |
| | Bromine | Br | 79.9 |
| | Iodine | I | 126.9 |

**Drawback**: Only limited triads were arranged in this pattern.

## Newland's Law of Octaves

In 1865, John Newland observed that in a series of elements arranged in the increasing order of atomic weights, 1st and 8th elements have same properties. Now, a days, 1st and 9th elements have same properties in that series because noble gases were discovered late.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Li | Be | B | C | N | O | F [Ne] | Na |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Mg | Al | Si | P | S | Cl [Ar] | K | Ca |



## Mendeleev's Periodic Table

"The physical and chemical properties of elements are a periodic function of atomic weights".

**Mendeleev** arranged elements in horizontal rows and vertical columns of a table in order of their increasing atomic weights in such a way that the elements with similar properties occupied the same vertical column or group. Vertical Colums are called groups which are numbered I to VIII group, each group is further subdivided into sub groups A and B. Horizontal rows are called **periods**.

The Periodic Table
Based on Mendeleev's Periodic Law

| 0 | I | II | III | IV | V | VI | VII | VIII | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H 1.01 | | | | | | | | | |
| HE 4.00 | Li 6.94 | Be 9.01 | B 10.8 | C 12.0 | N 14.0 | O 16.0 | F 19.0 | | | |
| Ne 20.2 | Na 23.0 | Mg 24.3 | Al 27.0 | Si 28.1 | P 31.0 | S 32.1 | Cl 35.5 | | | |
| Ar 40.0 | K 39.1 | Ca 40.1 | Sc 45.0 | Ti 47.9 | V 50.9 | Cr 52.0 | Mn 54.9 | Fe 55.9 | Co 58.9 | Ni 58.7 |
| | Cu 63.5 | Zn 65.4 | Ga 69.7 | Ge 72.6 | As 74.9 | Se 79.0 | Br 79.9 | | | |
| Kr 83.8 | Rb 85.5 | Sr 87.6 | Y 88.9 | Zr 91.2 | Nb 92.9 | Mo 95.9 | Tc (99) | Ru 101 | Rh 103 | Pd 106 |
| | Ag 108 | Cd 112 | In 115 | Sn 119 | Sb 122 | Te 128 | I 127 | | | |
| Xe 131 | Ce 133 | Ba 137 | La 139 | Hf 179 | Ta 181 | W 184 | Re 180 | Os 194 | Ir 192 | Pt 195 |
| | Au 197 | Hg 201 | Ti 204 | Pb 207 | Bi 209 | Po (210) | At (210) | | | |
| Rn (222) | Fr (223) | Ra (226) | Ac (227) | Th 232 | Pa (231) | U 238 | | | | |

Dobereiner's Triads · Known to Mendeleev · ★ Lanthanide Series · ★ Actinide Series · ★ Known to Ancients

**Defects in Mendeleev's Table-**

i. **Position of hydrogen**: Position of hydrogen was not justified.

ii. **Position of isotope**: Isotopes should be placed separately according to periodic law. But actually one place was given to all isotopes of an element.

iii. **Cause of periodicity**: Mendeleev could not explain why elements exhibit a periodicity in their properties when arranged in the order of increasing atomic weight.

iv. **Anomalous pairs of elements**: Some anomalous pairs were present in table. As Tellurium (128 u) comes in VI group before Iodine (127 u).

## Moseley's Peri

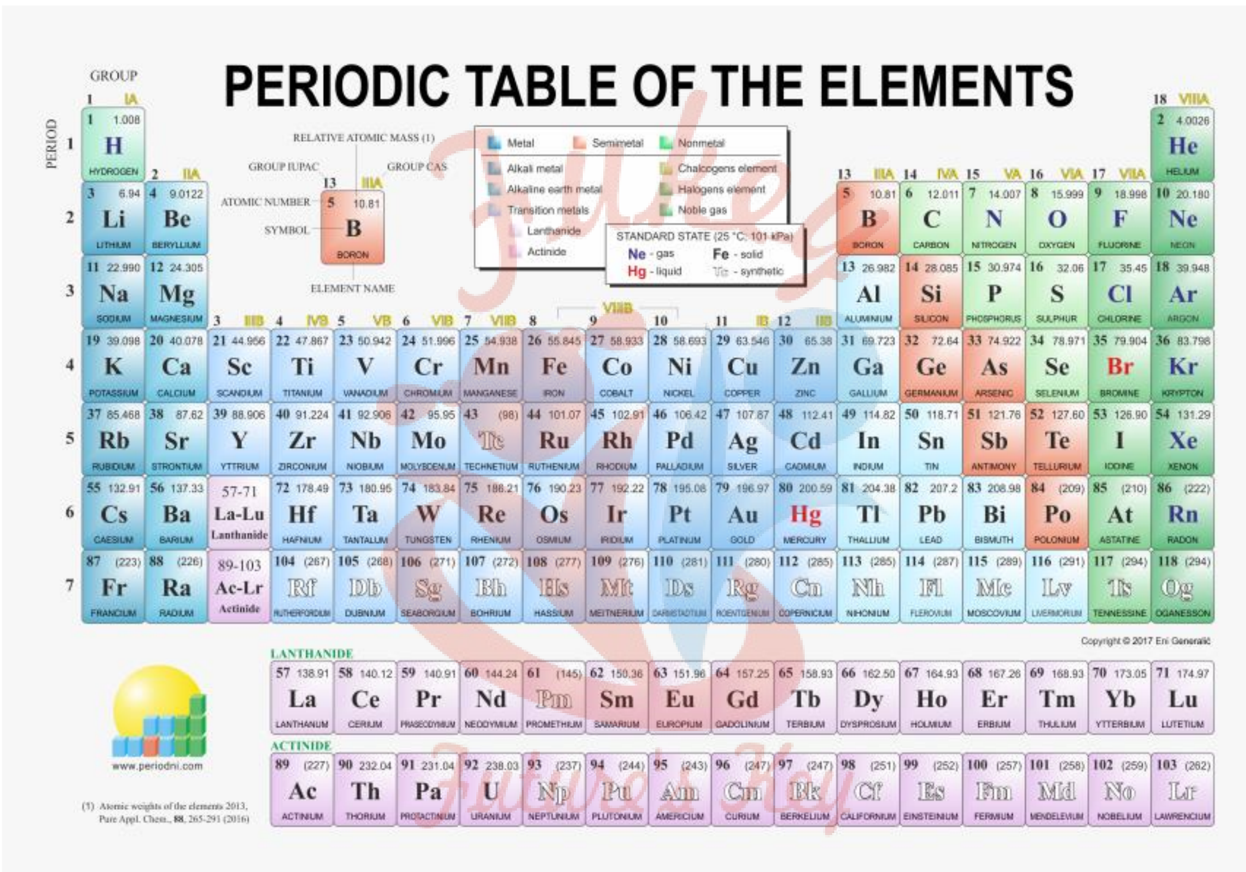
"The physical and chemical properties are the periodic function of their atomic numbers".

The long form of periodic table, also called Modem Periodic Table, is based on Modern periodic law. In this table, the elements have been arranged in order of increasing atomic numbers.

A modern version, the so-called "**long form**" of the **Periodic Table** of the elements, is the most convenient and widely used. The horizontal rows are called periods and the vertical columns, groups. Elements having similar outer electronic configurations in their atoms are arranged in vertical columns, referred to as groups or families. According to the recommendation of International Union of Pure and Applied Chemistry (IUPAC), the groups are numbered from 1 to

18 replacing the older notation of groups IA … VIIA, VIII, IB … VIIB and 0.

There are altogether seven periods. The period number corresponds to the highest principal quantum number (n) of the elements in the period. The first period contains 2 elements. The subsequent periods consists of 8, 8, 18, 18 and 32 elements, respectively. The seventh period is incomplete and like the sixth period would have a theoretical maximum of 32 elements. In this form of the Periodic Table, 14 elements of both sixth and seventh periods (lanthanoids and actinoids, respectively) are placed in separate panels at the bottom.




The IUPAC names are derived by using roots for three digit atomic number of the elements.

| Digit | Iupac Name | Symbol |
|---|---|---|
| 0 | nil | n |
| 1 | un | u |
| 2 | bi | b |
| 3 | tri | t |
| 4 | quad | q |
| 5 | pent | p |
| 6 | hex | h |
| 7 | sept | s |
| 8 | oct | o |
| 9 | enn | e |

A systematic nomenclature be derived directly from the atomic number of the element using the numerical roots for 0 and numbers 1-9. The roots are put together in order of digits which make up the atomic number and "ium" is added at the end. The IUPAC names for elements with Z above 100 are shown below:

| Atomic Number | Name according to IUPAC nomenclature | Symbol | IUPAC Official Name | IUPAC Symbol |
|---|---|---|---|---|
| 101 | Unnilunium | Unu | Mendelevium | Md |
| 102 | Unnilbium | Unb | Nobelium | No |
| 103 | Unniltrium | Unt | Lawrencium | Lr |
| 104 | Unnilquadium | Unq | Rutherfordium | Rf |
| 105 | Unnilpentium | Unp | Dubnium | Db |
| 106 | Unnilhexium | Unh | Seaborgium | Sg |
| 107 | Unnilseptium | Uns | Bohrium | Bh |
| 108 | Unniloctium | Uno | Hassium | Hs |
| 109 | Unnilennium | Une | Meitnerium | Mt |
| 110 | Ununnillium | Uun | Darmstadtium | Ds |
| 111 | Unununnium | Uuu | Rontgenium | Rg |
| 112 | Ununbium | Uub | Copernicium | Cn |
| 113 | Ununtrium | Uut | Nihonium | Nh |
| 114 | Ununquadium | Uuq | Flerovium | Fl |
| 115 | Ununpentium | Uup | Moscovium | Mc |
| 116 | Ununhexium | Uuh | Livermorium | Lv |
| 117 | Ununseptium | Uus | Tennessine | Ts |
| 118 | Ununoctium | Uuo | Oganesson | Og |

## Division of Elements into Blocks

**s-block**: The elements of Group 1 (alkali metals) and Group 2 (alkaline earth metals) which have $ns^1$ and $ns^2$ outermost electronic configuration belong to the s-Block Elements.

### Characteristics of s-Block elements,

i. Except Be and Mg, all impart characteristic colour to the flame.
ii. These have low ionisation energy.
iii. These are highly reactive.
iv. These are the highly electropositive elements.
v. All the elements are soft metals.
vi. They have low melting and boiling points.

**p-block**: The p-Block Elements comprise those belonging to Group 13 to 18 and these together with the s-Block Elements are called the Representative Elements or Main Group Elements. The outermost electronic configuration varies from $ns^2np^1$ to $ns^2np^6$ in each period.

### Characteristics of p-Block elements,

1. The compounds of p-block elements are generally covalent although their ionic character increases down the group.
2. From left to right 13 to 18, reducing character decreases.

3. The p-block elements generally show more than one oxidation state.
4. The reactivity of elements in a group generally decreases downwards.
5. At the end of each period is a noble gas element with a closed valence shell $ns^2$ $np^6$ configuration.

**d-block**: These are the elements of Group 3 to 12 in the centre of the Periodic Table. These are characterised by the filling of inner d orbitals by electrons and are therefore referred to as d-Block Elements. These elements have the general outer electronic configuration $(n\text{-}1)d^{1\text{-}10}ns^{0\text{-}2}$.

**Characteristics of d-Block elements**:

1. They are all metals with high melting and boiling points.
2. The compounds of the elements are generally paramagnetic in nature.
3. They mostly form coloured ions, exhibit variable valence (oxidation states).
4. They are of tenly used as catalysts.
5. These elements have high melting point.

**f-block**: The two rows of elements at the bottom of the Periodic Table, called the **Lanthanoids**, Ce(Z = 58) – Lu(Z = 71) and **Actinoids**, Th(Z=90) – Lr (Z=103) are characterised by the outer electronic configuration $(n\text{-}2)f^{1\text{-}14}(n\text{-}1)d^{0\text{–}1}ns^2$. The last electron added to each element is filled in f-orbital. These two series of elements are hence called the **Inner-Transition Elements** (f-Block Elements).

**Characteristics of f-Block elements**:

1. All actinoids are radioactive. Elements after uranium are known as transuranium element.
2. They form coloured compounds.
3. These two series of elements are called Inner Transition Elements (f-Block Elements).
4. They are all metals. Within each series, the properties of the elements are quite similar.
5. They generally have high melting and boiling points.

## Periodic Properties

The properties which generally have a regular trend along a group or period are called periodic properties. These are as given below:

- Atomic size
- Ionisation energy
- Electron gain enthalpy
- Electronegativity

i. **Atomic Size**: Atomic Radius is the distance from the centre of the nucleus to the outermost shell containing electron.

**Ionic Radius**: The ionic radii can be estimated by measuring the distances between cations and anions in ionic crystals. In general, the ionic radii of elements exhibit the same trend as the atomic radii.

**Cation**: The removal of an electron from an atom results in the formation of a cation. The radius of cation is always smaller than that of the atom.

**Anion**: Gain of an electron leads to an anion. The radius of the anion is always larger than that of the atom.

ii. **Ionisation energy**: It is the amount of energy required to remove the outer most electron from an isolated atom in its gaseous state. It is the measured in the unit of kJ/mole. It is denoted by ($\Delta_i H$).

$$M(g) - e^- \longrightarrow M^+(g)$$

iii. **Electron gain enthalpy**: It is the enthalpy change when an electron is added to the gaseous neutral atom. Electron gain enthalpy provides a measure of the ease with which an atom adds an electron to form anion. It is the measured in the unit of kJ/mole. It is denoted by ($\Delta_{eg}H$).

$$X(g) + e^- \longrightarrow X^-(g)$$

iv. **Electronegativity**: Electronegativity is a measure of the tendency of an element to attract bonded electron pair towards itself in a covalently bonded molecule.

## Periodic Trends in Chemical Properties along a Period

1. **Metallic character**: It decreases across a period, maximum on the extreme left (alkali metals).
2. **Non-metallic character**: It increases along a period, from left to right.
3. **Atomic Size**: It decreases across a period.
4. **Ionisation energy**: It increases along a period.
5. **Electron gain enthalpy**: It increases along a period.
6. **Electronegativity**: It increases along a period.
7. **Basic nature of oxides**: It decreases from left to right in a period.
8. **Acidic nature of oxides**: It increases from left to right in a period.

## Variation in Chemical Properties along a Group

1. **Metallic character**: Generally increases because increase in atomic size and hence decrease in the ionizatiorn energy of the elements in a group from top to bottom.

2. **Non-metallic character**: It generally decreases down a group. As electronegativity of elements decreases from top to bottom in a group.

3. **Atomic Size**: It increases along a group.

4. **Ionisation energy**: It decreases across a period.

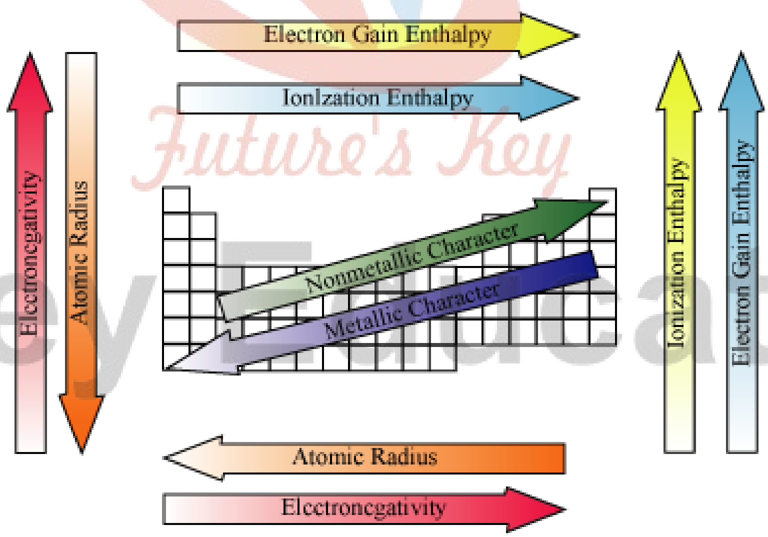
5. **Electron gain enthalpy**: It decreases across a period.

6. **Electronegativity**: It decreases across a period.

7. **Basic nature of oxides**: Since metallic character or electropositivity of elements increases in going from top to bottom in a group basic nature of oxidise naturally increases.

8. **Acidic character of oxides**: It generally decreases as non-metallic character of elements decreases in going from top to bottom in a group.

9. **Reactivity of metals**: It generally increases down a group. Since tendency to lose electron increases.




### Historical Development Of Periodic Table

Periodic table may be defined as the table which classified 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 separated from one another.

## Doebereiner's Triad

| Group | Elements and their Atomic Mass | | | Arithmetic mean of Atomic mass |
|---|---|---|---|---|
| A | Lithium(Li) | Sodium(Na) | Potassium(K) | $\frac{7.0+39.0}{2}=23.0$ |
| | 7.0 | 23.0 | 39.0 | |
| B | Calcium (Ca) | Strontium(Sr) | Barium(Ba) | $\frac{40.0+137.0}{2}=88.5$ |
| | 40.0 | 87.5 | 137.0 | |
| C | Chlorine(Cl) | Bromine(Br) | Iodine(I) | $\frac{35.0+127.0}{2}=81.0$ |
| | 35.0 | 80.0 | 127.0 | |
| | 55.8 | 58.9 | 58.6 | |

The first attempt towards the classification of elements was made by Johann Wolfgang Doebereiner, a German chemist in 1817.

He arranged similar elements in groups of three and showed that their atomic weights 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 Doebereiner's Triads and this generalisation was called Law of triads.

**Drawback**

The concept of triads could be applied only to a limited number of elements.

**Newlands's law of octaves**

In1865 ,an English chemist, John Alexander Newlands's observed at that:

When the lighter elements were arranged in order of their increasing atomic weights ,the properties of every 8th elements were similar to those of first one like the eighth note of a musical scale.This is called as Newlands's law of octaves.

**Drawback**

1) It was applicable to only lighter elements having atomic weights up to 40 u.

2) With the discovery of noble gases, the properties of the 8th element were no longer similar to those of the first one.

**Lothar Meyer arrangement**


In 1869, Lothar Meyer ,a German chemist, studied the physical properties of various element.

He Plotted a graph between the atomic volume and atomic weights of the elements and observed that the elements with similar properties occupied similar position on the curve.

1) The most strongly electropositive alkali metal occupy the peaks on the curve.

2) The less strongly electropositive alkaline earth metals occupy the descending position on the curve.

3) The most electronegative elements i.e. halogens occupy the ascending position on the curve.

Lothar Meyer proposed that the physical properties of the elements are a periodic function of the atomic weights.

He arranged the elements in the tabular form in order of their increasing atomic weights.

## Electronic configuration Of Elements

(1) The names are derived directly from the atomic numbers using numerical root for 0 and numbers from 1-9 and adding the suffix ium. The roots for the numbers 0-9 are:

| 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 |

(2) In certain cases, the names are shortened.bi ium and tri ium are shortened to bium and trium and enn nil shortened to ennil.

(3) The symbol of the element is then obtained from the first letters of the roots of numbers which make up the atomic number of the element.

An electron in an atom is characterised by a set of four Quantum numbers( n, l, m and s) and the Principal quantum number (n) defines the main energy level known as the shell.

Location of any element in the periodic table tells us the quantum number( n and l) of the last orbital filled.

**Electronic configuration of elements in period**

Each period in the periodic table indicates the value of n for the outermost or the valence shell. The total number of elements in each period is twice the number of orbitals available in the energy level that is being filled.

(1) The first period corresponds to the filling of electrons in the first energy shell i.e. (k shell),n=1.Since this energy shell has only 1 orbital i.e. 1s which can accommodate only 2 electrons, therefore, first period has only 2 elements.

(2) The second period corresponds to the filling of electrons in the second energy shell (L shell) i.e. n=2.This shell has 4 orbitals( one 2s and three 2p) which can accommodate 8 electrons, therefore second period contains 8 electron. It starts with Lithium (Z=3) and ends at neon (Z= 10).

(3) The third period corresponds to the filling of electron in the third shells, i.e. n=3.This shell has 9 orbitals ( one 3s, three 3p and five 3d) .3d orbital have even higher energy than 4s orbital. Therefore 3d orbitals are filled only after filling of 4s orbital. Third period involves the filling of only 4 orbitals( one 3s and three 3p) and thus contains 8 elements. It starts with sodium(Z=11) and ends at argon (Z= 18).

(4) The Fourth period corresponds to the filling of electrons in the fourth energy level, n=4. It starts with potassium( Z=19) and ends at calcium (Z= 20).

After the filling of 4s orbitals, the filling of five 3d orbitals begins since the energy of 3d orbital is lower than those of 4p orbitals but higher than that of 4s orbital. The filling of 4d and 4f orbital does not occur in this period since their energies are higher than that of even 5s orbital. The filling of the 3d orbital starts from scandium( Z= 21) and ends at Zinc( Z= 30).These 10 elements constitute the 3d transition series.

The filling of 4p orbital begins at gallium( Z=31)and ends at krypton( Z=36) which has the outer electronic configuration as 4s2 3d10 4p6 .In the 4th period, the filling of only 9 orbitals( one 4s, five 3d and three 4p ) occurs which can accommodate at the maximum 18 electrons. Therefore 4th period contain 18 electrons from potassium to Krypton.

(5) The fifth period also contains 18 elements since only 9 orbitals ( one 5s, five 4d and three 5p) are available for filling with electrons. It begins with rubidium(Z= 37) in which one electron enters 5s orbital. After the filling of 5s orbital, the filling of 4d orbital starts at yittrium (Z=39) and ends at cadmium (Z= 48).These ten elements constitute 4d transition series. Filling of 5p orbitals starts at indium (Z= 49) and ends at xenon ( Z=54).

(6) The sixth period corresponds to the filling of 6th energy level i.e. n= 6.Only 16 orbitals( one 5s, five 4d and three 5p) are available for filling with electrons, therefore 6th period contains 32 elements. It begins with caesium(Z=55) in which one electron enters the 6s orbital and ends up with radon(Z=86) in which the filling of 6p orbital is complete. After the filling of 6s Orbital, the next electron enters the 5d orbital and therefore the filling of seven 4f orbitals begins with Cerium(Z=58) and ends up with lutetium(Z=71).These 14 elements constitutes the first inner transition series called lanthanides or lanthanoids.

Filling of 5d orbitals which started at lanthanum continuous from hafnium( Z=72) till it is filled at mercury(Z=80). These 10 elements constitutes the 5d- transition series. After the filling of 5d orbitals, the filling of 6p orbitals starts at thallium(Z=81) and ends at the radon (Z=86).

(7) The seventh period corresponds to filling of 7th energy shells i.e. n=7. It also contain 32 elements corresponds to the filling of 16 orbitals(one 7s, seven 5f, five 6d and three 7p ).

After the filling of 7s orbital, the next two electrons enters the 6d orbitals and therefore the filling of seven 5f orbitals begin with proactinium(Z=91) and ends up with lawrencium(Z=103).

Thorium does not have any electron in the 5f orbital, yet get it is considered to be a f block element since its properties resemble more the f block element than the d block elements. These 14 elements from thorium(Z=90) to lawrencium(Z=103) constitute the second (or 5f) inner transition series which is called as actinides are actinoids.

Filling of 5d orbitals which started at actinum(Z=89) continues till it is completed at these Uub(Z=112).These 10 elements constitute the 6d transition series. The filling of 6d, orbital the filling of 7p orbitals begins at Uut (Z= 118) which ends at Uut (Z=118) which belongs to noble gas family.

The first three periods containing 2,8,8 elements and are known as short periods while the next three periods containing 18 ,18, 32 elements are called Long periods

**Group wise electronic configuration**

The elements in the same group or vertical column have similar valence shell electron electronic configuration i.e. they have the same number of electrons in the outer orbitals and hence have similar properties. Elements of group 1 all have ns1 valence shell electronic configuration. Elements of group 17 all have ns2 np5 valence shell electronic configuration.

## Prediction of period, group and block of a given element

The period of an element corresponds to the principal quantum number of the valence shell.

The block of an element corresponds to the type of orbital which receive the last electron.

The group of an element is predicted from the number of electrons in the valence shell or/and penultimate shell as follows:

a)For s block elements ,group number is equal to the number of valence electrons.

b) For p block elements ,group number is equal to 10+number of electrons in the valence shell.

c)For d block elements ,group number is equal to the number of electrons in a (n-1) sub shell + the number of electrons in valence shell.

Question :Write the electronic configuration of the element with atomic number 29. Predict the period, group number and block to which it belongs.

Answer : Z = 29 $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$

Elements receive the last electron in the 3d orbital ,therefore, it belongs to d block elements and its group number = No. of electrons in the penultimate shell and valence shell = 10+ 1 =11

The period of the element = No. of principal quantum number of the valence shell = $4^{th}$

## Summary-

1. **Periodic table**: Arrangement of elements in the increasing order of atomic number such that elements with similar properties fall under same vertical column.
2. **Group**: A vertical column of elements in the periodic table.
3. **Period**: A horizontal row of elements in the periodic table.
4. **Long form of periodic table** has 18 groups and 7 periods. Sixth period is the longest and first period is the smallest.
5. **s-Block elements**: Elements of groups 1 and 2. Their general valence shell electronic configuration is $ns^{1-2}$.

6. **p-Block elements**: Elements of groups 13, 14, 15, 16, 17 and 18. Their general valence shell electronic configuration is $ns^2np^{1-6}$.
7. **d-Block elements**: Elements of groups 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12. Also known as transition elements. Their general valence shell electronic configuration is $(n-1)d^{1-10}\ ns^{1-2}$. $_{46}Pd$ is exception ($4d^{10}\ 5s^0$).
8. **f-Block elements**: The two horizontal rows of elements at the bottom of the table. Also known as inner transition elements. Their general valence shell electronic configuration is $(n-2)f^{1-14}\ (n-1)d^{0-1}\ ns^2$.
9. **Covalent radius**: Half of the internuclear distance between two atoms of the element held by a single covalent bond.
10. **Van der Waal's radius**: Half of the internuclear distance between two nearest atoms belonging to two adjacent molecules in solid state.
11. **Metallic radius**: Half of the internuclear distance between two nearest atoms in the metallic lattice.
12. **Isoelectronic ions**: The ions having same number of electrons but different nuclear charge.

    **Example**: (i) $N^{3-}$, $O^{2-}$, $F^-$, $Na^+$, $Mg^{2+}$, $Al^{3+}$; (ii) $P^{3-}$, $S^{2-}$, $Cl^-$, $K^+$, $Ca^{2+}$, $Sc^{3+}$
13. Among isoelectric ions, greater the nuclear charge smaller is the size.
14. **Ionization enthalpy**: The minimum amount energy required to remove the outermost electron from an isolated gaseous atom of the element.
15. Ionization enthalpy increases along the period and decreases down the group.
16. Be, Mg, N, P and noble gases have exceptionally high values of ionization enthalpies due to their stable electronic configurations.
17. **Electron gain enthalpy**: The enthalpy change taking place when an electron is added to an isolated gaseous atom of the element.
18. Electron gain enthalpy becomes more negative as we move along the period and becomes less negative down the group.
19. Successive electron gain enthalpies are always positive.
20. Helium has the highest value of ionization enthalpy in periodic table.
21. Chlorine has the highest negative electron gain enthalpy in periodic table.
22. **Electronegativity**: It is the tendency of an atom in a molecule to attract towards itself the shared pair of electrons.
23. Fluorine is the most electronegative element whereas Caesium is the least electronegative element in periodic table.

24. Unlike ionisation energy and electron affinity, electronegativity is the property of atom of an element in combined state.

25. Electropositive or metallic character is related to the ionisation energy of the element. The elements having low I.E. are more electropositive or more metallic in character.

26. **Valence** of an element belonging to s or p-block is either equal to the number of valence electrons or eight minus the number of valence electron.

27. The chemical reactivity is maximum at the two extreme ends of the periodic table and is least in the centre.

28. Among alkali metals reactivity increases on descending the group while among halogens the reactivity decreases on descending the group.

29. The basic character of oxides decreases while the acidic character increases on going from left to right in a period.

30. Oxides of metals are generally basic while that of non-metals are acidic in nature.

31. The similarity between a pair of elements in period second and third located diagonally in the periodic table is called the **diagonal relationship**.

Fukey Future's Key

**Class : 11th Chemistry**
**Chapter- 3: Classification of Elements and Periodicity in Properties**

| Properties | Group | Period |
|---|---|---|
| (a) Atomic Radius : Distance from the centre of the nucleus to the outermost shell containing electrons. | Increases | Decreases |
| (b) Electron Gain Enthalpy : Energy released when a neutral isolated gabelous atom accepts an electron from anion. | Becomes less negative | Becomes more negative |
| (c) Ionization Energy: The minimum amount of energy required to remove the electron from the outmost orbit of an isolated atom in gaseous state. | Decreases | Increases |
| (d) Electronegativity : Tendency of an atom to attract the shared pair of electrons towards it "Group"self. | Decreases | Increases |
| (e) Electron Affinity | Decreases | Increases |
| (f) Valency: Number of univalent atoms which combine with an atom of given element. | No Change | Increase from 1 to 4 and then decrease from 4 to 0. |
| (g) Metallic Character: | Increases | Decreases |
| (h) Non–Metallic Character: | Decreases | Increases |

## Classification of Elements and Periodicity in Properties

### Periodic Trends in Properties of Elements

### Purpose

To ease out difficulty in studying individually the chemistry of all the elements and their compounds.

### Genesis of Periodic Classification

- Law of Triads: Johann Dobereiner (1829)
- Law of Octaves: John Alexander Newlands (1865)
- Periodic Law: Dimitri Mendeleev and Lothar Meyer. It states that the properties of the elements are periodic function of their atomic weights.
- Modern Periodic Law: Henry Moseley (1913) It states that the physical and chemical properties of the elements are periodic functions of their atomic numbers. ; Horizontal rows –Periods, Vertical columns – Groups –are numbered from 1 to 18.

### IUPAC Nomenclature of Elements with Atomic numbers > 100:

Derived from the atomic number of element using numerical roots for 0 and numbers 1-9 and "ium" is added at the end.

### Properties of Elements based on Electronic Configuration

- Electronic Configuration is the distribution of electrons into orbitals of an atom.
- In periods: Number of elements in each period is twice the number of atomic orbitals available in the energy level that is being filled.
- Group wise: Elements in same group have similar valence shell electronic configurations. Same number of electrons in outer orbitals and similar properties. These are classified into four blocks i.e., s-block, p-block, d-block and f-block.

### Periodic Table Classification based on Types of Elements

**f-Block: Elements**

- Also called as Inner Transition Elements.
- Contains Lanthanoids and Actinoids.
- Outer configuration ie $(n-2)f^{1-14}(n-1)d^{1-10}ns^{0-2}$
- All are metals.
- Actinoids are radioactive.

**d-Block: Elements**

- Group 3-12
- Outer configuration is $(n-1)d^{1-10}ns^2np^6$
- Forms coloured ions.
- Exhibit variable valence, paramagnetism.
- Also called as Transition elements.
- Some are used as catalysts.

**p-Block: Elements**

- Group 13 to 18.
- Also called as representatives or main group elements.
- Outermost configuration varies from $ns^2np^1$ to $ns^2np^6$
- At the end of period are low reactive noble gases.
- Halogens and Chalcogens have high negative electron gain enthalpies.
- Metallic character increases down the group.

**s-Block: Elements**

- Group 1 (alkali metals) and Group 2 (alkaline earth metals)
- Outermost configuration is $ns^1$ or $ns^2$
- Reactive with low IE.
- Metallic character and reactivity increases down the group.

# Important Questions

## Multiple Choice questions-

Question 1. The group number, number of valence electrons, and valency of an element with the atomic number 15, respectively, are:

(a) 16, 5 and 2

(b) 15, 5 and 3

(c) 16, 6 and 3

(d) 15, 6 and 2

Question 2. The d-block elements consist mostly of

(a) Monovalent metals

(b) All non-metals

(c) Elements which generally form stoichiometric metal oxide

(d) Many metals with catalytic properties

Question 3. Which of the following has the highest boiling point?

(a) Ne

(b) Xe

(c) Ar

(d) Kr.

Question 4. The chemistry of lithium is very similar to that of magnesium even though they are placed in different groups. Its reason is:

(a) Both are found together in nature

(b) Both have nearly the same size

(c) Both have similar electronic configuration

(d) The ratio of their charge and size (i.e. charge density) is nearly the same

Question 5. Which one of the following groupings represents a collection of isoelectronic species? (At. nos: Cs-55, Br-35)

(a) $Na^{+}$, $Ca^{2+}$, $Mg^{2+}$

(b) $N^{3-}$, F–, Na+

(c) Be, $Al^{3}$+, $Cl^{-}$

(d) $Ca^{2+}$, $Cs^{+}$, Br

Question 6. Which of the following has the maximum number of unpaired electrons?

(a) $Mg^{2+}$

(b) $Ti^{3+}$

(c) $V^{3+}$

(d) $Fe^{2+}$

Question 7. In the periodic table, the element with atomic number 16 will be placed in the group

(a) Third

(b) Fourth

(c) Fifth

(d) Sixth

Question 8. Representative elements are those which belong to

(a) p and d – Block

(b) s and d – Block

(c) s and p – Block

(d) s and f – Block

Question 9. Which pair of elements belongs to same group?

(a) Elements with atomic no. 17 and 38

(b) Elements with atomic no. 20 and 40

(c) Elements with atomic no. 17 and 53

(d) Elements with atomic no. 11 and 33

Question 10. The most electronegative element of the periodic table is

(a) Iodine

(b) Sulphur

(c) Oxygen

(d) Fluorine.

Question 11. In the third period of the Periodic Table the element having smallest size is

(a) Na

(b) Ar

(c) Cl

(d) Si

Question 12. The element with highest second ionization energy is

(a) Cl

(b) S

(c) Na

(d) Mg

Question 13. Which of the following properties generally decreases along a period?

(a) Ionization Energy

(b) Metallic Character

(c) Electron Affinity

(d) Valency.

Question 14. Increasing order of electronegativity is

(a) Bi < P < S < Cl

(b) P < Bi < S < Cl

(c) S < Bi < P < Cl

(d) Cl < S < Bi < P

Question 15. Which of the following oxides is amphoteric in character?

(a) $SnO_2$

(b) $CO_2$

(c) $SiO_2$

(d) CaO

## Very Short:

1. An element is present in the third period of the p-block. It has 5 electrons in its outermost shell. Predict its group. How many unpaired electrons does it have?

2. An element X with Z = 112 has been recently discovered. Predict its electronic configuration and suggest the group in which it is present.

3. The electronic configuration of an element is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$. Name the period and the group to which it belongs?

4. Arrange Cl, Cl–, $Cl^+$ ion in order of increasing size.

5. Arrange the following in increasing order of size.

$N^{3-}$, $Na^+$, $F^-$, $O^{2-}$, $Mg^{2+}$

6. Give the formula of one species positively charged and one negatively charged that will be isoelectronic with Ne.

7. Argon has atomic number 18 and belongs to the 3rd period and 18th group. Predict the

group and period for the element having atomic number 19.

## Short Questions:

1. Do elements with high I.E. have high E.A.?
2. What is a periodic classification of elements?
3. Distinguish between s and p block elements.
4. Explain why ionization enthalpies decrease down a group of the Periodic Table.
5. Why does the first ionization enthalpy increase as we go . from left to right across a given period of the Periodic Table.
6. How do atomic radii vary across a period with an atomic number in the periodic table?

## Long Questions:

1. Electronic configuration of the four elements are given below: Arrange these elements in increasing order of their metallic character. Give reasons for your answer.
   (i) $[Ar]4^{s2}$
   (ii) (ii) $[Ar]3d^{10}\ 4s^2$
   (iii) $[Ar]3d^{10}\ 4s^2\ 4p^6\ 5s^2$
   (iv) $[Arl\ 3d^{10}\ 4s^2\ 4p^6\ 5s^1$
2. Explain the important general characteristics of groups in the modem periodic table in brief.
3. Explain the electronic configuration in periods in the periodic table. „
4. Explain the variation of valence in the periodic table.

## Assertion Reason Questions:

1. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

   **Assertion (A) :** Generally, ionisation enthalpy increases from left to right in a period.

   **Reason (R) :** When successive electrons are added to the orbitals in the same principal quantum level, the shielding effect of inner core of electrons does not increase very much to compensate for the increased attraction of the electron to the nucleus.

   (i) Assertion is correct statement and reason is wrong statement.

(ii) Assertion and reason both are correct statements and reason is correct explanation of assertion.

(iii) Assertion and reason both are wrong statements.

(iv) Assertion is wrong statement and reason is correct statement.

2. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

   **Assertion (A) :** Boron has a smaller first ionisation enthalpy than beryllium.

   **Reason (R) :** The penetration of a 2s electron to the nucleus is more than the 2p electron hence 2p electron is more shielded by the inner core of electrons than the 2s electrons.

   (i) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

   (ii) Assertion is correct statement but reason is wrong statement.

   (iii) Assertion and reason both are correct statements and reason is correct explanation for assertion.

   (iv) Assertion and reason both are wrong statements.

## Case Study Based Question:

1. Comprehension given below is followed by some multiple choice questions. Each question has one correct option. Choose the correct option. In the modern periodic table, elements are arranged in order of increasing atomic numbers which is related to the electronic configuration. Depending upon the type of orbitals receiving the last electron, the elements in the periodic table have been divided into four blocks, viz, s, p, d and f. The modern periodic table consists of 7 periods and 18 groups. Each period begins with the filling of a new energy shell. In accordance with the Arfbau principle, the seven periods (1 to 7) have 2, 8, 8, 18, 18, 32 and 32 elements respectively. The seventh period is still incomplete. To avoid the periodic table being too long, the two series of f-block elements, called lanthanoids and actinoids are placed at the bottom of the main body of the periodic table.

   (1) The element with atomic number 57 belongs to

   (a) s-block

   (b) p-block

   (c) d-block

   (d) f-block

(2) The last element of the p-block in 6th period is represented by the outermost electronic configuration.

(a) 7s2 7p6

(b) 5f14 6d10 7s2 7p0

(c) 4f14 5d10 6s2 6p6

(d) 4f14 5d10 6s2 6p4

(3) Which of the elements whose atomic numbers are given below, cannot be accommodated in the present set up of the long form of the periodic table?

(a) 107

(b) 118

(c) 126

(d) 102

(4) The electronic configuration of the element which is just above the element with atomic number 43 in the same group is ________.

(a) 1s2 2s2 2p6 3s2 3p6 3d5 4s2

(b) 1s2 2s2 2p6 3s2 3p6 3d5 4s3 4p6

(c) 1s2 2s2 2p6 3s2 3p6 3d6 4s2

(d) 1s2 2s2 2p6 3s2 3p6 3d7 4s2

(5) The elements with atomic numbers 35, 53 and 85 are all ________.

(a) Noble gases

(b) Halogens

(c) Heavy metals

(d) Light metals

2. Read the passage given below and answer the following questions:

When an electron is added to a gaseous atom in its ground state to convert it into a negative ion, the enthalpy change accompanying the process is called the electron gain enthalpy ($\Delta e_g$ H). It is a direct measure of the ease with which an atom attracts an electron to form anion.

$$X(g) + e^- \longrightarrow X^-(g); \Delta H = \Delta e_g H$$

The most stable state of an atom is the ground state. If an isolated gaseous atom is in excited state, comparatively lesser energy will be released on adding an electron. So, electron gain enthalpies of gaseous atoms must be determined in their ground states. Therefore, the terms ground state and isolated gaseous atom has been also included in the definition of electron gain enthalpy. Like ionisation enthalpy, electron gain enthalpy is measure either in electron volts per atom or kJ per mole.

(1) Noble gases have positive electron gain enthalpy due to:

(a) Stable configuration

(b) Large size

(c) High reactivity

(d) Unstable configuration

(2) The electron gain enthalpy of O or F is less than that of S or Cl. It is due to:

(a) Small size

(b) Less repulsion

(c) Large size

(d) High electronegativity

(3) The electron gain enthalpy (in kJ/mol) of fluorine, chlorine, bromine and iodine, respectively, are:

(a) -333, -325, -349 and -296

(b) -296, -325, -333 and -349

(c) -333, -349, -325 and -296

(d) -349, -333, -325 and -296

(4) Why beryllium has higher ionization enthalpy than boron?

(a) More penetration of s-electron

(b) More penetration of p-electron

(c) Large size

(d) Small size

## Answer Key:

### MCQ

1. (a) 15, 5 and 3
2. (d) Many metals with catalytic properties
3. (b) Xe
4. (d) The ratio of their charge and size (i.e. charge density) is nearly the same
5. (b) $N^{3-}$, $F^{-}$, Na+
6. (d) $Fe^{2+}$

7. (d) Sixth
8. (c) s and p – Block
9. (c) Elements with atomic no. 17 and 53
10. (d) Fluorine.
11. (b) Ar
12. (c) Na
13. (b) Metallic Character
14. (a) Bi < P < S < Cl
15. (a) $SnO_2$

## Very Short Answer:

1. It belongs to the 15th group (P). It has 3 unpaired electrons.
2. Rn] $5f^{14}$ $6d^{10}$ $7s^2$. It belongs to the 12th group.
3. Third-period Group 17.
4. CP < Cl < CP.
5. $Mg^2 + < Na^+ < F^- < O^{2-} < N^{3-}$
6. $Na^+$, $F^-$.
7. Group I, Period 4th.

## Short Answer:

**Ans: 1.** Normally is true that the elements with haying high value of I.E. have a high value of E affinity. But however, there are marked exceptions. It is seen that elements, with stable electronic configurations, have very high values of I-Energies as it is difficult to remove electrons as is the case with 15th and 18th group elements but in such case, electron cannot be added easily so that is why elements of 15th group have almost zero E.A. and elements of 18th group have got zero E.A. whereas their Ionization energy values are very high.

**Ans: 2.** By periodic classification of the elements we mean the arrangement of the elements in such a way that the elements with similar physical and chemical properties are grouped together and for this various scientists made contributions but however the contributions made by Mendeleev are of great significance and he gave a periodic table which called as Mendeleev's Periodic 'Table which was older and replaced by the long form of the periodic table.

**Ans: 3.** They can be distinguished as follows: s block elements:

1. They have got the general configuration of the valence shell, $ns^{1-2}$.
2. They are all metals.
3. Their compounds are mostly ionic.
4. They are generally strong reducing agents.
5. They mostly impart characteristic color to the flame.
6. They have low ionization energies.
7. They show fixed oxidation states,

p block elements:

1. The valence shell electronic configuration of p block elements in $ns^2\ p^{1-6}$.
2. They are mostly non-metals.
3. Their compounds are mostly covalent.
4. They are generally strong oxidizing agents.
5. Mostly they do not impart color to the flame.
6. They have got a comparatively higher value of I.E.
7. They show variable oxidation states.,

**Ans: 4.** The decrease in ionization enthalpies down any group is because of the following factors:

1. There is an increase in the number of the main energy shells
2. moving from one element to another.
3. There is also an increase in the magnitude of the screening effect due to the gradual increase in the number of inner electrons.

**Ans: 5.** The value of ionization enthalpy increases with the increase in atomic number across the period.

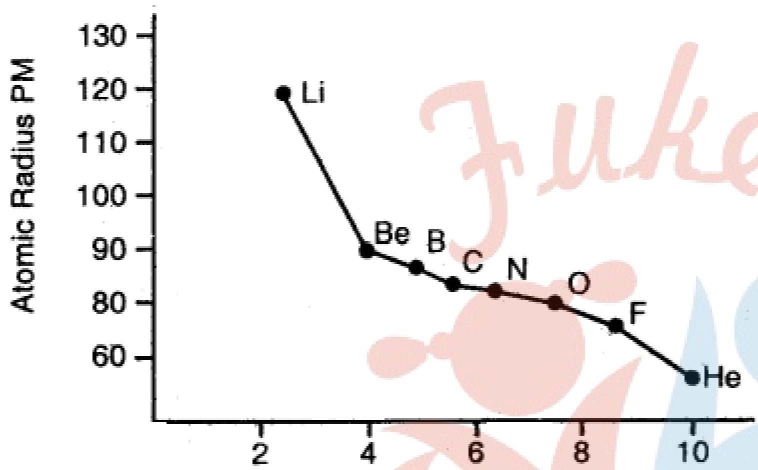
This is due to the fact that in moving across the period from left to right.,

1. Nuclear charge increases regularly by one unit.
2. The progressive addition of electrons occurs at the same level.
3. Atomic size decreases.

This is due to the gradual increase in nuclear charge and a simultaneous decrease in atomic size the electrons are more and more tightly bound to the nucleus. This results in a gradual increase in ionization energy across the period.

**Ans: 6.** Variation of Atomic radii across a period: atomic radii decrease with the increase in the atomic number in a period. For example, atomic radii decrease from lithium to fluorine in the second period.

In moving from left to right across the period, the nuclear charge increases progressively by one unit but the additional electron goes" to the same principal shell. As a result, the electron cloud is pulled closer to the nucleus by increased effective nuclear charge. This causes a decrease in atomic size.




Variation of the atomic radius with an atomic number across the second period

## Long Answer:

**Ans: 1.** (i) [Ar]4s2 is Calcium metal with At. no. = 20.

(ii) $[Ar]3d^{10} 4s^2$ is Zinc metal with At. no. = 30.

(iii) $[Ar]3d^{10} 4s^2 4p^6 5s^2$ is Strontium metal with At. no. = 38.

(iv) $[Ar] 3d^{10} 4s^2 4p^6$, $5s^1$ is*Rubidium metal with At. no. = 37.

Alkali metals are the most metallic, followed by alkaline earth metals and transition metals. Among alkali metals – Rubidium (37) is the most metallic. Among alkaline earth metals (Ca, Sr) Sr (Strontium) is more metallic than Calcium (Ca) as the metallic character increases from top to bottom in a group. Zinc – the transition metal is the least metallic. Thus metallic character increases from

Zn < Ca < Sr < Rb or (ii) < (i) < (iii) < (iv)

**Ans: 2.** The elements of a group show the following important similar characteristics.

(0 Electronic configuration. All elements in a particular group have similar outer electronic configuration e.g., all elements of group I', i.e., alkali metals have $ns^1$ configuration in their valency shell. Similarly, group 2 elements (alkaline Earths) Haye $ns^2$ outer configuration and halogens (group 17) have $ns^2$ np5 configuration (where n is the

outermost shell).

(it) Valency. The valency of an element depends upon the number of electrons in the outermost shell. So elements of a group show the same valency, e.g., elements of group 1 show + 1 valency and group 2 show + 2 valencies i.e. valency i.e., NaCl > MgC$^{l2}$ etc.

(iii) Chemical properties. The chemical properties of the elements are related to the number of electrons in the outermost shell of their atoms. Hence all elements belonging to the same group show similar chemical properties. But the degree of reactivity varies gradually from top to bottom in a group. For example, in group 1 all the elements are highly reactive metals but the degree of reactivity increases from Li to Cs. Similarly, elements of group 17, i.e., halogens: F, Cl, Br, I are all non-metals and they're- reactivity goes on decreasing from top to bottom.

**Ans: 3**. Each successive period in the periodic table is associated with the filling Up of the next higher principal energy level (n – 1, n – 2, etc.). It can be readily seen that the number of elements in each period is twice the number of atomic orbitals available in the energy level that is being filled. The first period starts with the filling of the lowest level (1s) and has thus the two elements – hydrogen ($1s^1$) and helium ($1s^2$) when the first shell (K) is completed. The second period starts with lithium and the third electron enters the 2s orbital.

The next element, beryllium has four electrons and has the electronic configuration $1s^2$ $2s^2$. Starting from the next element boron, the 2p orbitals are filled with electrons when the L shell is completed' at neon ($2s^2$ $2p^6$). Thus there are 8 elements in the second period. The third period (n = 3) being at sodium, and the added electron enters a 3s orbital. Successive filling of 3s and 3p orbitals give rise to the third period of 8 elements from sodium to argon.

The fourth period (n = 4) starts at potassium with the filling up of 4p of 4s orbital. Before the 4p orbital is filled, the filling up of 3d orbitals becomes energetically favorable and we come across the so-called 3d transition series of elements. The fourth period ends at krypton with the filling up of the 4p orbitals. Altogether we have 18 elements in the fourth period. The fifth period (n = 5) beginning with rubidium is similar to the fourth period and contains the 4d transition series starting at yttrium (Z = 39).

This period ends at xenon with the filling up of the 5p orbitals. The sixth period (n = 6) contains 32 elements and successive electrons enter 6s, 4/, 5d, and 6p orbitals, in that order. Filling up of the 4/ orbitals being with cerium, (Z = 58) and ends at lutetium (Z = 71) to give the 4/-inner transition series which is called the lanthanide series. The seventh period (n = 7) is similar to the sixth period with the successive filling up of the 7s, 5f, 6d, and 7p orbitals and includes most of the man-made radioactive elements.

This period will end at the element with atomic number 118 which would belong to the noble gas family. Filling up of the 5f orbitals after actinium (Z = 89) gives the 5f-inner transition series known as the actinide series. The 4f and 5f transition series of elements are placed separately in the periodic table to maintain its structure and to preserve the principle of classification by keeping elements with similar properties in a single column.

**Ans: 4.** Variation of valence in a group as well as across a period in the periodic table occurs as follows:

1. In a group: All elements in a group show the same valency. For example, all alkali metals (group 1) show a valency of 1+. Alkaline earth metals (group 2) show a valency of 2+.

However, the heavier elements of p-block elements (except noble gases) show two valences: one equal to the number of valence electrons or 8-No. of valence electron# and the other two less. For example, thallium (Tl) belongs to group 13. It shows valence of 3+ and 1+.

Lead (Pb) belongs to group 14. If shows valance of 4+ and 2+.

Antimony (Sb) and Bismuth (Bi) belong to group 15. They show valence of 5+ and 3+ being more stable.

This happens due to the non-participation of tie two s-electrons present in the valence shell of these elements. This non-participation of one pair of s-electrons in bonding is called the inert-pair effect.

3. In a period: The number of the valence electrons increases – in going from left to right in a period of the periodic table. Therefore, the valency of the elements in a period first increases, and then decreases.

## Assertion Reason Answer:

1. (ii) Assertion and reason both are correct statements and reason is correct.
2. (iii) Assertion and reason both are correct statements and reason is correct.

## Case Study Answer:

**1. Answer:**

(1) (c) d-block
(2) (c) 4f14 5d10 6s2 6p6
(3) (c) 126
(4) (a) 1s2 2s2 2p6 3s2 3p6 3d5 4s2
(5) (b) Halogens

**2. Answer:**

(1) (a) Stable configuration
(2) (a) Small size
(3) (c) -333, -349, -325 and -296
(4) (a) More penetration of s-electron