Electronic configurations of elements and the periodic table

^{11}Na = 1s² 2s² 2p⁶ 3s¹ — Period, Group

- The distribution of electrons into orbitals of an atom is called its electronic configuration.
- An element's location in the periodic table reveals the quantum numbers of the last orbital filled.

(i) Electronic configuration in periods :- 1s → 2s 2p → 3s 3p

- The period indicates the value of 'n' for the outermost or valency shell.
- 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.

1st period → 1s¹ 1s² (H) (He) — contain only two elements

2nd period → 2s 2p (Li) (Be) — contain 8 elements from Li to Ne

3rd period → 3s 3p — contain 8 elements from Na to Ar

- 4th period → 4s, 3d, 4p (K) (Ca) (Sc) — contain 18 elements from K to Kr
  - Now in this period, it may strike that before the '4s' orbital is filled, filling up of '3d' orbitals begins unexpectedly formerly and we term as the 3d series. This starts from Scandium (Z=21). The '3d' orbitals are filled at Zinc (Z=30) with electronic configuration 3d¹⁰4s².
- 5th period - Begin with Rubidium and contain 4d transition series starting at Yttrium (Z=39). This period ends at Xe (Z=54). This period also contain 18 elements.
- 6th period - This contain 32 elements. Successive electrons enter 6s, 4f, 5d and 6p orbitals, in the order - filling up of the 4f - Inner transition series which is called the lanthanoid series.
- 7th period - This period ends at the element with atomic number 118. In 7th period similar to the 6th period with the successive filling up of the 5f, 6d and 7p orbitals and includes most of the man-made radioactive elements filling up of the 5f orbitals again actinium (Z=89) gives 5f - Inner transition series known as the actinoid series.

NB: 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.

(ii) Groupwise Electronic configurations :- Li 1s² 2s¹, Na 1s² 2s² 2p⁶ 3s¹, K 1s² 2s² 2p⁶ 3s² 3p⁶ 4s¹

- Elements in the same vertical column or group have similar valence shell electronic configurations, i.e. the same number of electrons in the outer orbitals, for 1st and similar properties.

For example, the Group 1 elements [Alkali Metals] all have ns¹ valence shell electronic configuration. Thus it can be seen that the properties of elements have periodic dependence upon its atomic number and not on relative atomic mass.

Electronic configurations and Types of Elements: s, p, d - f - blocks:

- The elements in a vertical column of the Periodic Table constitute a group or family and exhibit similar chemical behaviour. This similarity arises because these elements have the same number and same distribution of electrons in their outermost orbitals.
- we can classify elements into 4-block viz. s-block, p-block, d-block and f-block, depending on the type of atomic orbitals that are being filled with electrons.

- We include Gas exception in this categorization.
  (i) Helium, He belongs to the s-block but its positioning in the p-block along with other group 18 elements is justified because it has a completely filled valence shell (1s²) and as a result, exhibits properties characteristic of other noble gases.
  (2) The other exception is Hydrogen. It has only one s-electron and hence can be placed in group 1 (Alkali metals). It can also gain an electron to achieve a noble gas arrangement and hence it can behave similar to a group 17 (Halogen family) elements. Because it is a special case, we shall place Hydrogen separately at the top of periodic Table.

(a) The s-block elements :-

- These in which differentiating electrons enter into outermost s-subshell.
- There have ns¹ or ns² outermost electronic configuration.
  - ns¹ Alkali metals (Group 1) - Li, Na, K, Rb, Cs, Fr
  - ns² Alkaline earth metals (Group 2) - Be, Mg, Ca, Sr, Ba, Ra
- They are all reactive metals with low ionization enthalpies.
- The valence of Group 1 is +1 because they lose outermost electron easily.
- The valency of Group II is +2 because they lose outermost electrons easily.
- The metallic character and the reactivity increase as we go down the group.

Elections ↓ during removal from outer most shell: Li > Na > K > Rb > Cs

NB: Because of high reactivity they are never found free in nature.

- The compounds of the s-block elements, with exception of those lithium and beryllium are predominantly ionic.
- these are soft metals having low melting points and boiling points.
- They are strong reducing agents.

(b) The p-block elements :-

- The p-block elements comprise those belonging to group 13-18.
- s-block & p-block elements together known as Representative elements or Main Group Elements.
- Their general electronic configuration is ns^2np^{1-6} (ns² np¹⁻⁶)
  for example,
  - 13th column (IIIA) - ns²np¹ → Boron
  - 14th column (IVA) - ns²np² → Carbon.
  - 15th column (VA) - ns²np³ → Nitrogen → Pnictogens
  - 16th column (VIA) - ns²np⁴ → Oxygen → Chalcogens
  - 17th column (VIIA) - ns²np⁵
  - 18th column (Zero) - ns²np⁶ - noble/inert/rare gases
- As the end of each period is a noble gas element with a closed valence shell ns²np⁶ configuration.
- All the orbitals in valence shell of the noble gases are completely filled by electrons and it is very difficult to alter this stable arrangement by addition or removal of electrons. Thus noble gases thus exhibit very low chemical reactivity.
- Preceding the noble gas family are two chemically important groups of non-metals. They are halogens (Gp 17) and chalcogens (Gp16). These two groups of elements have highly reactive electron gain enthalpy and readily add one or two electrons respectively to attain the stable noble gas configuration.
- The non-metallic character increases as we move from left to right across a period and metallic character increases as we go down the group.

(c) The d-Block Elements (Transition elements)

- These are the elements of Group 3 to 12 in the centre of the periodic table.
- These are characterized by the filling of inner d-orbitals by electrons and are members referred to as d-block elements.
- Their general outer electronic configuration is $(n-1)d^{1-10}ns^{0-2}$ except for Pd where its electronic configuration is $4d^{10}5s^0$.
- They are all metals.
- They mostly formed coloured ions, exhibit variable valence (oxidation states), paramagnetism and actively used as catalyst.
- Zn, Cd, Hg which have electronic configuration $(n-1)d^{10}ns^2$ do not show most of the properties of transition elements - as orbital than elements are completely filled in the ground state as well as in their common oxidation states. Therefore, they are not regarded as transition elements.
- Transition metals form a bridge between the chemically active metals of s-block elements and the less active elements of Groups 13 & 14 and thus known as "Transition Elements".

NB: Elements having two incomplete outer shells are known as transition elements.

(d) The f-Block Elements (Inner Transition elements)

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

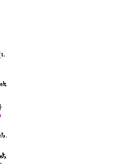

Fig. 3.4 The long form of the periodic table consisting of the main group elements (s- and p-blocks), transition elements (d-block) and inner transition elements (f-block)

- They are all metals.
- within each series, the properties of the elements are quite similar.
- The chemistry of the early actinoids is more complicated than the corresponding lanthanoids, due to the large number of oxidation states possible for these actinoid elements.

- Actinoid elements are radioactive.
- Many of the actinoid elements have been made only in microgram quantities or even less by nuclear reactions and their chemistry is not fully studied.

NB: The elements after uranium are called Trans uranium elements

exception :- $(n-1)d^{1/10}$ $(n-1)d^{1-10}$ ns^{0-2}

- Cr → 4s¹ 3d⁵ 4s¹
- Cu → 4s¹ 3d¹⁰ 4s¹
- Nb* → 4s¹ 4d⁴ 5s¹
- Mo* → 4s¹ 4d⁵ 5s¹
- Ru* → 4s¹ 4d⁷ 5s¹
- Rh* → 4s¹ 4d⁸ 5s¹
- Pd* → 4s⁰ 4d¹⁰ 5s⁰
- Ag* → 4s¹ 4d¹⁰ 5s¹
- Pt* → 4s¹ 5d⁹ 6s¹
- Au* → 4s¹ 5d¹⁰ 6s¹
- Cm → 4s¹ 6d¹ 5s²
- Gd → 4s¹ 5d¹ 6s²
- Ce → 4s¹ 4f¹ 5s²
- Pa → 4s¹ 5f² 6s²
- Fm → 4s¹ 5f¹² 6s²
- Md → 4s¹ 5f¹³ 6s²
- No → 4s¹ 5f¹⁴ 6s²
- Lr → 4s¹ 5f¹⁴ 6d¹ 6s²

Metals, Non-metals and Metalloids :

- Other broad classification of elements are based on their properties.
- The elements can be divided into Metals and Non-Metals.

- Metals :-
  - In comparison more than 80% of all known elements and appear on top side of the periodic table.
  - Metals are usually solid at room temperature (Hg is exception; gallium and cesium also have very low melting points (30.5 & 28.5°C, respectively))
  - Metals usually have high melting and boiling points.
  - They are good conductors of heat and electricity.
  - They are malleable (can be flattened into thin sheets by hammering) and ductile (can be drawn into wires)
- Non-metals :-
  - They are located on the top right hand side of the periodic table.
  - In fact, in period, the property of elements change from metallic on the left to non-metals on the right.
  - They are generally solids or gases at room temp.
  - They have low melting and boiling points (Bromine and carbon are exceptions)
  - They are poor conductors of heat and electricity. Most non-metallic solids are brittle and are neither malleable nor ductile.
- The elements become more metallic as we go down a group.
- The non-metallic character increases as one goes from left to right across the Periodic Table
- Metalloid :-
  - The elements like silicon, germanium, arsenic, antimony and tellurium bordering step-like line and running diagonally across the periodic table.
  - They show properties that are characteristic of both metals and non-metals. These elements are called semi-metals or Metalloids.