# Ionization Potential or Ionization Energy.

The electrons in an atom are attracted by the nucleus. When an electron is to be removed then work is done against this nuclear attraction. In other words energy is required to remove an electron from an atom. To understand the details of chemical behavior of an element we must have an indication of the energy with which an atom binds its electrons. This is obtained by the measurement of ionization potential or ionization energy. It may be defined as **the energy required to remove an electron from the outermost orbit of an isolated gaseous atom in its ground state**. It is expressed in electron volts (eV) or kilo calories per gram atom. In an atom, the energy required to remove first electron from a gaseous atom is called first ionization energy. The energy required to remove one electron from a unipositive ion to form a bipositive ion is called second ionization energy. Second ionization energy is higher than the first. The reason is that in unipositive ion left after the removal of one electron from the atom, the electrons are more firmly bound to the nucleus than in the atom. Hence more energy is needed to remove the second electron.

$A \rightarrow A^{+} + e^{-1}$ (First $I.E.$)

$A^{+} \rightarrow A^{+2} + e^{-1}$ (Second $I.E.$)

$A^{+2} \rightarrow A^{+3} + e^{-1}$ (Third $I.E.$)

Similarly, third ionization energy is even more than second ionization energy.

(1) **Variation of ionization energy in periodic table**

(i)**Ionization energy decreases in a group as the atomic number increases**. It is based on the fact that as we move down a group, the size of atom increases, and the outer electrons become farther away from the nucleus thus reducing the force of attraction and hence ionization energy decreases.

| Li | Na | K | Rb | Cs |
|---|---|---|---|---|
| 5.4 eV | 1. eV | 4.3 eV | 4.2 eV | 3.9 eV |

(ii) **Ionization energy increases along a period with increase in atomic number**. This is due to the size of atom since it decreases along a period and outer electrons are most strongly attracted by the nucleus and hence more energy is required to remove the electron.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Li | Be | B | C | N | O | F | Ne |
| 5.4 eV | 9.3 eV | 8.3 eV | 11.3 eV | 14.6 eV | 13.6 eV | 17.0 eV | 21.6 eV |

(iii) The ionization energies of inert gases are greater than that of their immediate neighbour. It is due to their complete octet $ns^2p^6$ configuration which is highly stable. Therefore, it is very difficult to remove an electron from the outermost orbit of an inert gas.

(2) **Factors affecting the value of ionization energy**

(i) **Size of atom:** With an increase in atomic size, the ionization potential is reduced, since the distance of the outermost electron from the nucleus increases and hence the force of attraction decreases.

(ii) **The charge on the nucleus:**With an increase in the nuclear charge, there is an increase in force of attraction of nucleus for electrons making the removal of the electrons more difficult. Thus an increase in nuclear charge increases the ionization potential.

(iii) **The shielding or screening effect of inner shells**:The valence electrons in a multi–electron atom are pulled by the nucleus but are repelled by the electrons of the inner shells. The valence electrons, therefore, do not experience the total pull of the nucleus. Instead the total pull of the nucleus is reduced by the electrons in inner shells. This effect of reducing the force of attraction of nucleus by the inner shells is called screening effect. This effect is exhibited maximum by $s^2p^6$ (the most stable) shell. Therefore, the ionization energy of K is much less than Cu, however, both have one electron in their fourth shell.

$$K^{19} = 1s^2, 2s^2p^6, 3s^2p^6, 4s^1 \; ; \; Cu^{29} = 1s^2, 2s^2p^6, 3s^2p^6d^{10}, 4s^1$$

The ionization energy of K is 4.33 eV while that of Cu is 7.72 eV. This is due to a large screening effect of $s^2p^6$, penultimate orbit in K while $s^2p^6d^{10}$, penultimate orbit in Cu which exhibit little screening effect.

(iv) **Type of electrons involved** : Ionization energy also depends upon the type, i.e., s, p, d or f, electrons which are to be removed, s –electrons are closer to the nucleus and are more tightly held as compared to p, d or f electrons. Hence, ionization energy decreases in the order of s > p > d > f orbitals.

(v) **Completely filled or half-filled sub-shells:** According to Hund's rule, completely filled or half-filled orbitals are more stable. Therefore, it is comparatively difficult to remove the electrons from these shells. The ionization energy of Be (9.3 eV) is more than B (8.3 eV) because Be has $2s^2$ configuration of the outermost orbit which is fully filled. Similarly, nitrogen (14.6 eV) has more ionization energy than oxygen (13.6 eV) because nitrogen has outermost shell configuration as $2s^2p^3$ in which p shell is half filled and is more stable. Similarly, ionization energy of Mg is more than Al and that of P is more than S.

(3) **Relative ionization energies**

$IE_1$ and $IE_2$ of the 2nd period elements

$IE_1$: Li < B < Be < C < O < N < F < Ne

$IE_2$: Be < C < B < N < F < O < Ne < Li

$IE_1$ of elements with very high values

Cl < H < O < Kr < N < Ar < F < Ne < He

$IE_1$ and $IE_2$ of the 3rd period elements

$IE_1$: Na < Al < Mg < Si < S < P < Cl < Ar

$IE_2$: Mg < Si < Al < P < S < Cl < Ar < Na

(4) **Importance of ionization energy**

(i)Lower is the ionization potential of an element, more would be its reducing power and also reactivity.

(ii) It gives rough estimate about the basic character of the elements.

(iii) The relative values of ionization potential and electron affinity of two elements are related to the nature of bond formed during their combination.

(iv) Theionization potentials provide an indication about the number of valence electron(s) in an atom; the abnormally high value indicates that the electron removed is other than the valence electron.

**For example**, $IE_1$, $IE_2$ and $IE_3$ values are 5.39, 75.62 and 122.42 eV. Since the values shows sudden jump, it indicates that the number of valence electron in its atom is one. Similarly, values of $IE_1$, $IE_2$ and $IE_3$ as 9.32, 18.21 and 153.85 eV indicate that the number of valence electrons in its atom is two.