IONISATION POTENTIAL OR IONISATION ENERGY OR IONISATION ENTHALPY

Minimum energy required to remove most loosly held outer most shell e^- in ground state from an isolated gaseous atom is known as ionisation potential.

(Isolated → Without any bonding with other atom)

Successive Ionisation Energy

(a) For an atom M, successive ionisation energies are as follows -

$M + E_1 \longrightarrow M^+ + e^-$ $E_1 = I^{st}$ Ionisation Potential

$M^+ + E_2 \longrightarrow M^{+2} + e^-$ $E_2 = II^{nd}$ Ionisation Potential

$M^{+2} + E_3 \longrightarrow M^{+3} + e^-$ $E_3 = III^{rd}$ Ionisation Potential

I^{st} Ionisation Potential < II^{nd} Ionisation Potential < III^{rd} Ionisation Potential

(b) Electron can not be removed from solid state of an atom, it has to convert in gaseous form, Energy required for conversion from solid state to gaseous state is called Sublimation energy.

(c) Ionisation Potential is always an endothermic process ($\Delta H = +ve$)

(d) It is measured in eV/atom (electron volt/atom) or Kcal/mole or KJ/mole

2. Factors affecting ionisation potential

(a) **Atomic size** : Larger the atomic size, smaller is the Ionisation Potential It is due to that the size of atom increases the outermost electrons e^-. farther away from the nucleus and nucleus loses the attraction on that electrons and hence can be easily removed.

$$\boxed{\text{Ionisation Potential} \propto \frac{1}{\text{Atomic size}}}$$

(b) **Effective nuclear charge (Z_{eff})** : Ionisation potential increases with the increase in nuclear charge between outermost electrons and nucleus.

$$\boxed{\text{Ionisation Potential} \propto \text{Effective nuclear charge}}$$

(c) Screening effect : Higher is the screening effect on the outer most electrons causes less attraction from the nucleus and can be easily removed, which is leading to the lower value of Ionisation Potential

$$\boxed{\text{Ionisation Potential} \propto \frac{1}{\text{Screening effect}}}$$

(d) Penetration power of sub shells :

(i) Order of attraction of subshells towards nucleus (Penetration power) is -

$s > p > d > f$

(ii) As subshell is more closer to nucleus so more energy will be required to remove e^- in comparision to p,d & f. Ex.

	Be	B
	$1s^2, 2s^2$	$1s^2, 2s^2 2p^1$
Ionisation Potential	Be >	B

After loosing one e^-, B attains electronic configuration of Be, so IInd ionisation potential of B is more than Be. IInd **Ionisation Potential of B > Be**

(e) Stability of half filled and fully filled orbitals :

(i) Half filled p^3, d^5, f^7 or fully filled s^2, p^6, d^{10}, f^{14} are more stable than others so it requires more energy.

Ex. N O

$1s^2, 2s^2 2p^3$ $1s^2, 2s^2 2p^4$ Ist Ionisation Potential order is $O < N$

Because of half filled p-orbitals in N, its ionisation energy (stability) is higher than O.

Ist ionisation potential order Na < Al < Mg

(ii) Because s-orbital in Mg is completely filled and its penetration power is also higher than p-orbital (Al).

IInd ionisation potential order $Mg^+ < Al^+ < Na^+$

(2,8,1) (2,8,2) (2,8)

Periodic variation of ionisation energy

(a) **Variation in period among the representative elements:** Ionisation energies generally increases along the period because in moving left to right in a period the effective nuclear charge per outermost electron increases while the corresponding principal quantum number remain same.

(b) **Variation in a group among the representative elements :** The ionisation energy generally decreases in moving from top to bottom because the size increases due to the increase of the principal quantum number. On the other hand the effective nuclear charge Zeff for the outermost electron remains almost the same along the group.

Exception

(a) Ionisation Potential of Al < Ionisation Potential of Ga (While Ionisation Potential decreases down the group it is due to Transition contraction)

577 kj mol^{-1} 579 kj mol^{-1}

(b) Ionisation Potential of Hf > Ionisation Potential of Zr (While Ionisation Potential should decreases down the group. It is due to lanthanide contraction)

760 kj mol^{-1} 5d 674 kj mol^{-1} 4d

(c) In a period atomic size decreases and zeff increases so removal of electron becomes difficult and ionisation potential increases. But N, Be, P, Mg, show high ionisation energy than corresponding of next element.

$$\xrightarrow{\text{Li} \quad \text{Be} \quad \text{B} \quad \text{C} \quad \text{N} \quad \text{O} \quad \text{F} \quad \text{Ne}}$$

atomic size decreases, zeff increases, Ionisation Potential increases.

Order of ionisation potential Li < B < Be < C < O < N < F < Ne

Applications of ionisation potential

(a) **Metallic and non metallic character**

Metallic ⟶ Ionisation Potential Low (Na, K, Rb etc.)

non metallic ⟶ Ionisation Potential High (F, Cl, Br etc.)

$$\boxed{\text{Ionisation Potential} \propto \frac{1}{\text{Metallic property}}}$$

(b) **Reducing character**

$$\boxed{\text{Reducing character} \propto \frac{1}{\text{Ionisation Potential}}}$$

(i) IA group has minimum ionisation potential so they are strong reducing agents in gaseous state (Li < Na < K < Rb < Cs)

(ii) IA group – In Aqueous state

reducing character Li > K $\simeq$ Rb > Cs > Na

As the degree of hydration is more in Li due to high charge density.

(iii) VIIA group has maximum ionisation potential so they are strong oxidising agents (F > Cl > Br > I)

(c) **Stability of oxidation states :**

(i) If the difference between two successive ionisation potential $\geq$ 16eV then lower oxidation state is stable.

Ex. $Na \longrightarrow Na^+$ I

$$\left.\begin{array}{ll} Na \longrightarrow Na^{+} & I^{st} \text{ ionisation potential} \\ Na^{+} \longrightarrow Na^{+2} & II^{nd} \text{ ionisation potential} \end{array}\right\} 42.7 \text{ eV}$$

Difference of ionisation potential > 16 eV So Na^+ is more stable.

(ii) If the difference between two successive ionisation potential $\leq$ 11 then higher oxidation state is stable.

Ex.

$$\left.\begin{array}{ll} Mg \longrightarrow Mg^{+} & I^{st} \text{ ionisation potential} \\ Mg^{+} \longrightarrow Mg^{+2} & II^{nd} \text{ ionisation potential} \end{array}\right\} 7.4 \text{ eV}$$

Difference of ionisation potential < 11 eV So Mg^{+2} is more stable.

$Al \longrightarrow Al^+$

} 12.8 eV So Al^+ is more stable

$Al^+ \longrightarrow Al^{+2}$

} 6.0 eV So Al^{+3} is more stable

$Al^{+2} \longrightarrow Al^{+3}$

{ Al^+ is stable only in gaseous state

Al^{+3} is stable in liquid and solid state.

Ionization energy in KJ mol^{-1}

Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H 1311																H 1311	He 2372
2	Li 520	Be 899											B 801	C 1086	N 1403	O 1314	F 1681	Ne 2080
3	Na 496	Mg 737											Al 577	Si 786	P 1012	S 999	Cl 1255	Ar 1521
4	K 419	Ca 590	Sc 631	Ti 656	V 650	Cr 652	Mn 717	Fe 762	Co 758	Ni 736	Cu 745	Zn 906	Ga 579	Ge 760	As 947	Se 941	Br 1142	Kr 1351
5	Rb 403	Sr 549	Y 616	Zr 674	Nb 664	Mo 685	Tc 703	Ru 711	Rh 720	Pd 804	Ag 731	Cd 876	In 558	Sn 708	Sb 834	Te 869	I 1191	Xe 1170
6	Cs 376	Ba 503	La 541	Hf 760	Ta 760	W 770	Re 759	Os 840	Ir 900	Pt 870	Au 889	Hg 1007	Tl 589	Pb 715	Bi 703	Po 813	At 912	Rn 1037
7	Fr	Ra	Ac															