IONIZATION ENERGY: →

The ease with which an electron can be removed from an atom is measure by its ionization energy. In other words, It is the minimum energy needed to remove an e^- from a gas phase atom

$A(g) \longrightarrow A^+(g) + e^-(g)$ $I = E(A^+g) - E(A_g)$

I.E is an ~~a~~ endothermic process, since it requires energy. Ionization energy values are expressed in electron volt per atom (eV/atom) kilo-calories per mole.

Successive I.E: → second, third etc I.E →

The first I.E (IE_1), is the energy required to remove the least tightly bound electron from the neutral atom. The second ionization energy (IE_2), is the energy required to remove the least tightly bound electron from the resulting cation and so on.

$$M(g) - e^- \longrightarrow M^+(g), \quad \Delta H = +IE_1$$

$$M^+(g) - e^- \longrightarrow M^{2+}(g), \quad \Delta H = +IE_2$$

$$M^{2+}(g) - e^- \longrightarrow M^{3+}(g) \quad \Delta H = +IE_3$$

All the above process can also be written as

$$M(g) \xrightarrow{+IE_1, -e} M^+(g) \xrightarrow{+IE_2, -e} M^{2+}(g) \xrightarrow{+IE_3, -e} M^{3+}(g)$$

IE_1, IE_2 IE_3 etc are called successive IE of the neutral gaseous atoms. It has be observed that of an given element M(g), the magnitude of successive IE are in the increasing order,

$$IE_1 < IE_2 < IE_3 < \text{------}$$

(b) Explanation:→ Successive IE requires increasingly higher energies. Thus, the 2nd IE (IE_2) of an element (the energy needed to remove an e^- from the cation, M^+) is higher than its first ionization energy IE_1. lly, its 3rd IE (IE_3) is higher still. The explanation is that the higher the positive charge of a species the greater the energy needed to remove an e^- from the species. Moreover, when a e^- is removed, Z_{eff} increase and the atom contracts. It is then more difficult to remove an e^- from the smaller & more compact cation.

The difference in IE is greatly magnified when the e^- is removed from a closed shell of the atom. For eg:→, first IE of lithium (IE_1) is 513 KJmol^{-1}, but its 2nd IE (IE_2) is 7297 KJ mol^{-1}, more than ten times greater.

$$Li\,(1s^2 2s^1) \xrightarrow[513\,KJmol^{-1}]{IE_1} Li^+(1s^2) \xrightarrow[7297\,KJm]{IE_2} Li^{2+}(1s^1)$$

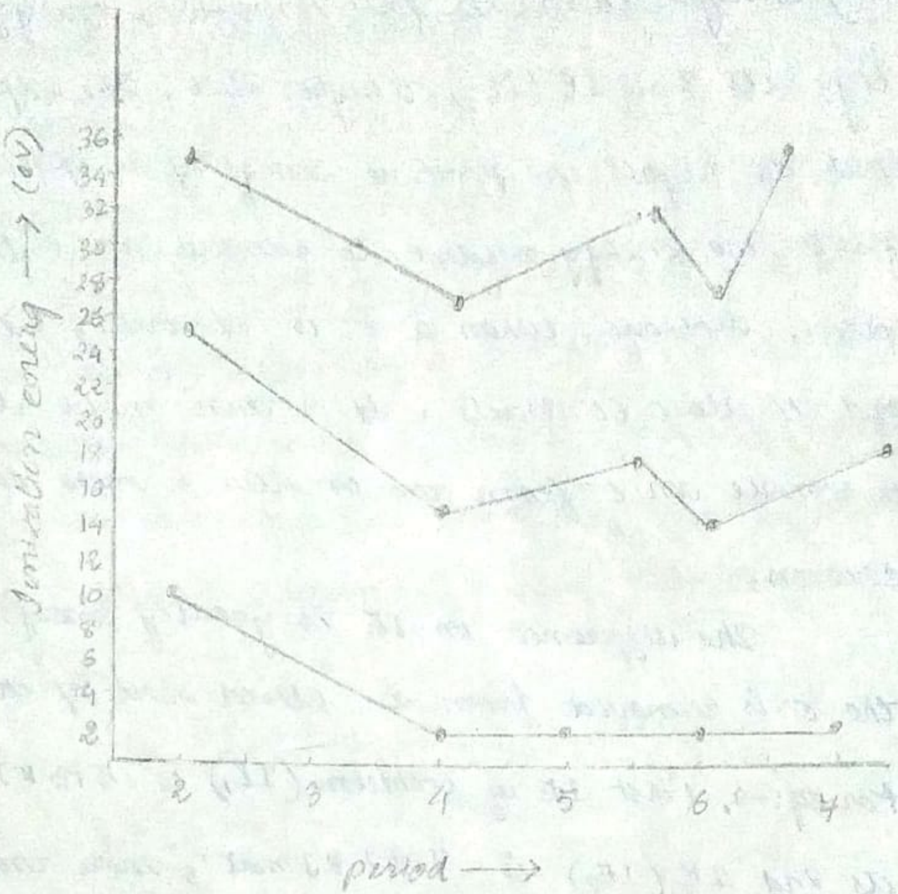
$$Na\,(1s^2 2s^2 2p^6 3s^1) \xrightarrow[495\,KJmol]{IE_1} Na^+(1s^2 2s^2 2p^6) \xrightarrow[4562\,KJmol]{IE_2} Na^{2+}(1s^2 2s^2 2p^5)$$

This is happened because the electron must then be extracted from a compact orbital in which in interact strongly with the nucleus.

<u>Note</u>:→ The pattern of successive IE down a group is far from simple. For eg:→ The first, 2nd and 3rd IE of group 13 elements are considered.

although they lie in the expected order

$IE_1 < IE_2 < IE_3$ there is no simple trend.



Examples:⟶ Rationalize the following values for successive Ionization energies for B, where $\Delta_{ion}H(N)$ is ~~that~~ the N^{th} enthalpy of variation.

N	1	2	3	4	5
$\Delta_{ion}H(N)$ (kJ mol^{-1})	0.807	2.433	3.666	25.033	32.834.

Answer:⟶ The electronic configuration of B is $1s^2 2s^2 2p^1$.

$$B(1s^2 2s^2 2p^1) \xrightarrow{IE_1} B^{+}(1s^2 2s^2) \xrightarrow{IE_2} B^{2+}(1s^2 2s^1)$$

$$\downarrow IE_3$$

$$B^{5+}(1s^0) \xleftarrow{IE_5} B^{4+}(1s^1) \xleftarrow{IE_4} B^{3+}(1s^2)$$

The first ionization energy corresponding to removal of the e^- in the p-orbital. This electron is shielded from nuclear charge by the core 1s shell and the 2s sub-shell. Therefore the IE_1 is low.

The second value (IE_2) corresponding to the removal of the e^- from the B^+ cation. This e^- is more difficult to remove on account of the effective nuclear charge and completely filled arrangement, hence IE_2 value is higher than that of IE_1. Removal of the other 2s e^- even need higher energy because the effective nuclear charge further increases.

There is a large increase betn IE_3 and IE_4 because the 1s shell lies at very low energy as it experiences almost the full nuclear charge and also it lies in a shell with $n=1$. Therefore I.E$_4$ achieve very high range. The final e^- to be removed experiences no shielding nuclear charge so IE_5 is also high.