Chapter 2. Electrons in atom

Atomic structure

- nucleus → proton (+)
- nucleus → neutron (0)(neutral)
- electron (−)

~ proton number = atomic number

~ nucleon number = proton number + neutron number

~ In neutral atom: proton = electron

~ $^{64}_{29}Cu$ $p=29$ $e^-=29$ $n=64-29=35$

~ $^{80}_{35}Br$ $p=35$ $e^-=35$ $n=80-35=45$

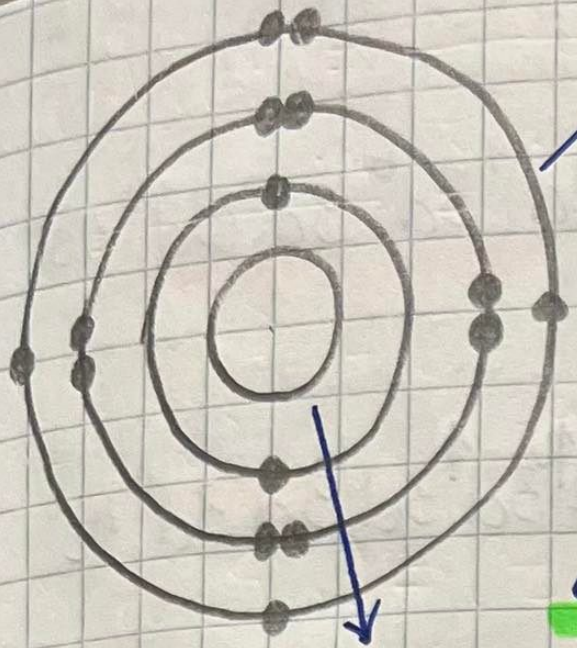
~ $^{35}_{17}Cl + e^- \rightarrow {}^{35}_{17}Cl^-$

$p=17$, $e^-=17$, $n=18$ → $p=17$, $e^-=18$, $n=18$

$^{40}_{20}Ca \rightarrow {}^{40}_{20}Ca^{2+} + 2e^-$

$p=20$, $e^-=20$, $n=20$ → $p=20$, $e^-=18$, $n=20$

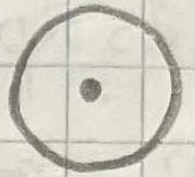
ion 2+



electron shell → energy level of electron

↳ subshell (orbital(s)) → electron orbit

Orbital: s, p, d, f



S: spherical

p: lobe

d:

s	p	d	f
(1)	(3)	(5)	(7)

15

2S 2p 2p 2p

3S 3p 3p 3p 3d 3d 3d 3d 3d

4S 4p 4p 4p 3d 3d 3d 3d 3d 4f 4f 4f 4f 4f 4f 4f

~ $^{32}_{16}S$ $e^- = 16$ $1s^2 2s^2 2p_x^2 2p_y^2 2p_z^2 3s^2 3p_x^2 3p_y^1 3p_z^1$

~ $^{24}_{12}Mg$ $e^- = 12$ $1s^2 2s^2 2p_x^2 2p_y^2 2p_z^2 3s^2$

* $^{52}_{24}Cr$ $e^- = 24$ $3d > 4s$ energy level, бага нь эхэнд авна.

$1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2\ 3s^2\ 3p_x^2\ 3p_y^2\ 3p_z^2\ 3d^1\ 3d^1\ 3d^1\ 3d^1\ 3d^0\ 4s^2$

3d orbital energy level higher than 4s.

symmetric structure

more stable

★ $^{64}_{29}Cu \quad e^- = 29$

$1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2\ 3s^2\ 3p^6\ 3d^2\ 3d^2\ 3d^2\ 3d^2\ 3d^1\ 4s^2$

symmetric structure

outer shell p orbital ⇒ detailed structure

Ionisation energy, ΔH

First ionisation energy: Energy needed to remove 1 e^- from each atom in mole of atoms of the element in gaseous state to form one mole of gaseous 1+ ions.

$Br(g) \longrightarrow Br^+(g) + e^-$, $\Delta H_{i1} = \ldots kJ\,mol^{-1}$

$Br^+(g) \longrightarrow Br^{2+}(g) + e^-$, $\Delta H_{i2} = \ldots kJ\,mol^{-1}$

$Br^{9+}(g) \longrightarrow Br^{10+}(g) + e^-$, $\Delta H_{i10} = \ldots kJ\,mol^{-1}$ → always increase

Successive ionisation energy: remove electron from atom until only the nucleus is left.

~ $Na(g) \longrightarrow Na^+(g) + e^-$ $\Delta H_{i1} = 494\,kJ\,mol^{-1}$

$Na^+(g) \longrightarrow Na^{2+}(g) + e^-$ $\Delta H_{i2} = 4560\,kJ\,mol^{-1}$

$Na^{2+}(g) \longrightarrow Na^{3+}(g) + e^-$ $\Delta H_{i3} = 6940\,kJ\,mol^{-1}$

$Na^{3+}(g) \longrightarrow Na^{4+}(g) + e^-$ $\Delta H_{i4} = 9540\,kJ\,mol^{-1}$

$Na^{4+}(g) \longrightarrow Na^{5+}(g) + e^-$ $\Delta H_{i5} = 13400\,kJ\,mol^{-1}$

$Na^{5+}(g) \longrightarrow Na^{6+}_{(g)} + e^-$ $\Delta H_{i6} = 16600$ kJ mol^{-1}

$Na^{6+}(g) \longrightarrow Na^{7+}_{(g)} + e^-$ $\Delta H_{i7} = 20100$ kJ mol^{-1}

$Na^{7+}(g) \longrightarrow Na^{8+}_{(g)} + e^-$ $\Delta H_{i8} = 25500$ kJ mol^{-1}

$Na^{8+}(g) \longrightarrow Na^{9+}_{(g)} + e^-$ $\Delta H_{i9} = 28900$ kJ mol^{-1}

$Na^{9+}(g) \longrightarrow Na^{10+}_{(g)} + e^-$ $\Delta H_{i10} = 141000$ kJ mol^{-1}

$Na^{10+}(g) \longrightarrow Na^{11+}_{(g)} + e^-$ $\Delta H_{i11} = 158700$ kJ mol^{-1}

~ Successive ionisation energy

↳ **always increase**: the charge on the ion gets greater as each electron is removed.

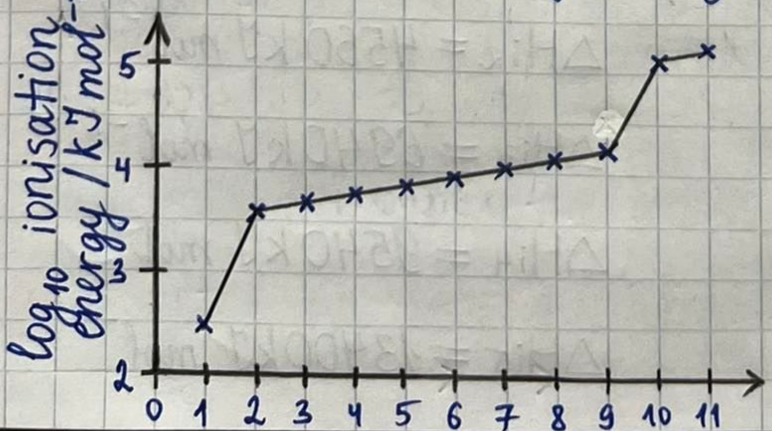
~ As each electron is removed there is a greater attractive force between the positively charged protons in the nucleus and the remaining negatively charged electrons. Therefore, more energy is needed to overcome these attractive forces.

The factors that influence ionisation energies

1) The site of the **nuclear charge** (proton number)

2) **Distance** of outer electrons from the nucleus. ★ дундаас нь идэж, үүх

3) **Shielding effect**: Full inner shells of electrons prevent the full nuclear charge being felt by the outer electrons.

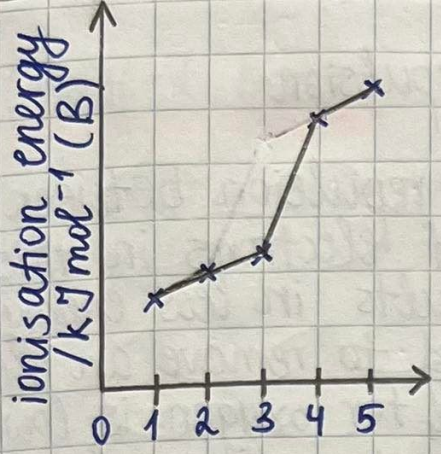


$Na \rightarrow 1s^2 2s^2 2p^6 3s^1$

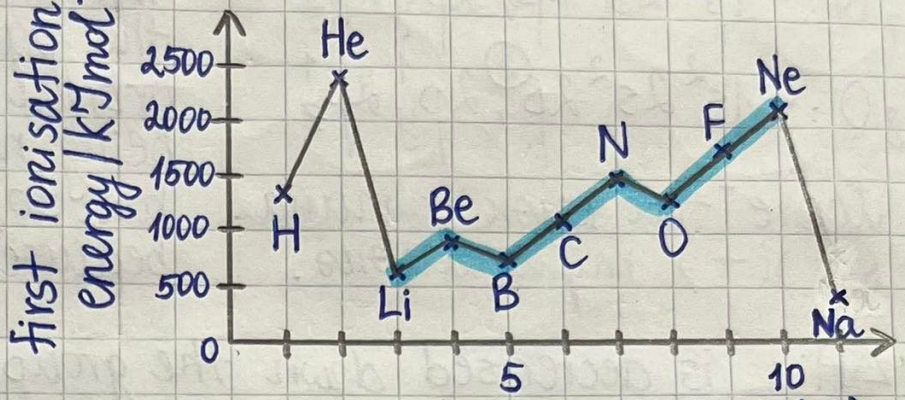
$\log_2 2^3 = 3$

$\log_2 8 = 3$ $\log_4 64 = 3$

number of electrons removed



2.6. Patterns in ionisation energies in the Periodic Table



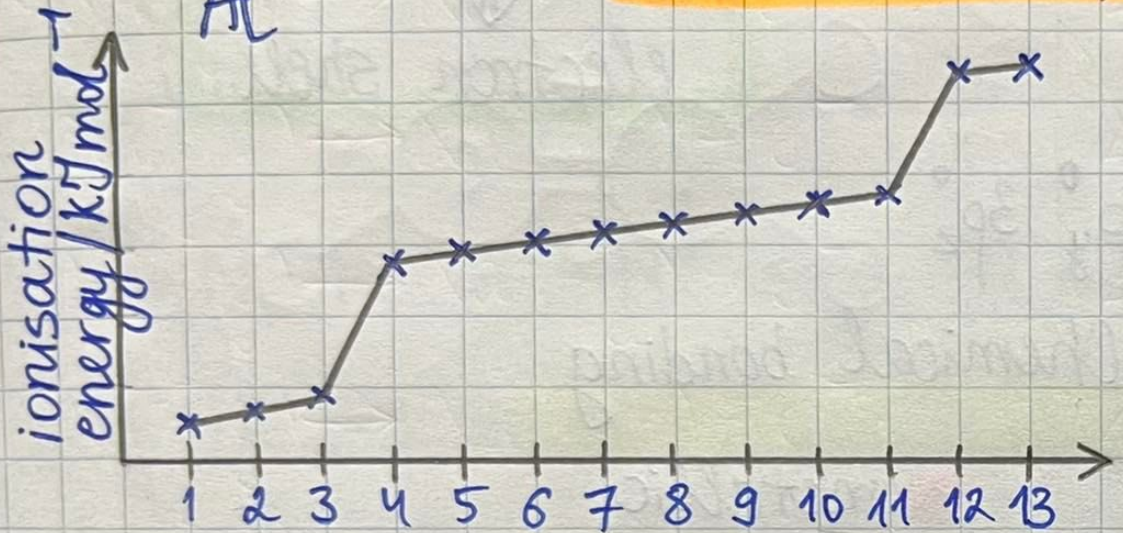
General increase:

- nuclear charge increases
- the distance between nucleus and the outer shell electron remains reasonably constant
- the shielding by inner shells remains constant.

↖ main factor

- He–Li: rapid decrease
  - ↳ distance between nucleus and outer electron increases
  - ↳ shielding by inner shells increases
- Be–B: decrease $^{9}_{4}Be: 1s^2 2s^2$ $^{11}_{5}B: 1s^2 2s^2 2p_x^1 2p_y^0 2p_z^0$
  - ↳ 2p subshell slightly further away from the nucleus than 2s subshell

Al



B – O : ΔH_{i1} increases.

↳ nuclear charge is increased.

↳ same number of electron shell

N–O: ΔH_{i1} decreases → spin-pair repulsion / electron

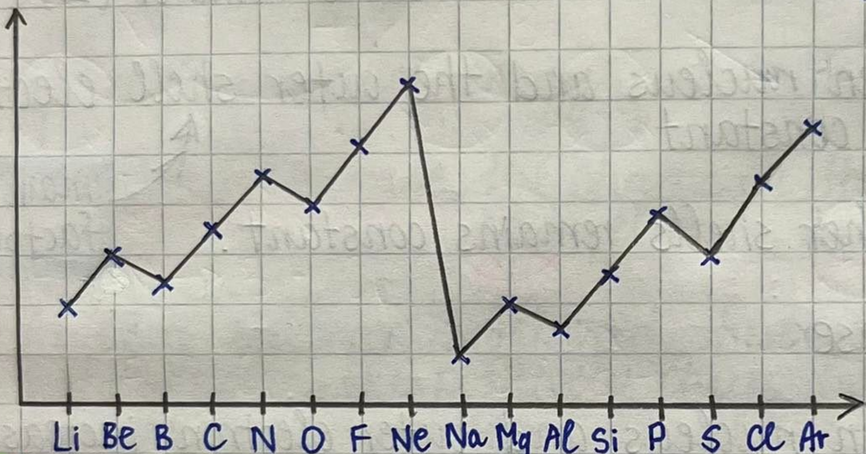
$_7N$: $1s^2 2s^2 2p_x^1 2p_y^1 2p_z^1$ ①

$_8O$: $1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$ ②

Хос e^--оос хялэн салгана.
(−)(−) түлхэлцэнэ.

The extra repulsion between the pair of electrons in this orbital results in less energy being needed to remove an electron. So, IE_1 for oxygen is lower, because of spin-pair repulsion.

~ ΔH_{i1} is decreased down the group. (shell number increased) (shielding effect increased)



Электрон байгуулалт нь s дэд дүүрч байвал s block, p дэд дүүрч байвал p block element.

⇓

s block → Group 1,2

p block → Group 3–8

d block → transition elements

f block → lanthanide, Actinide series

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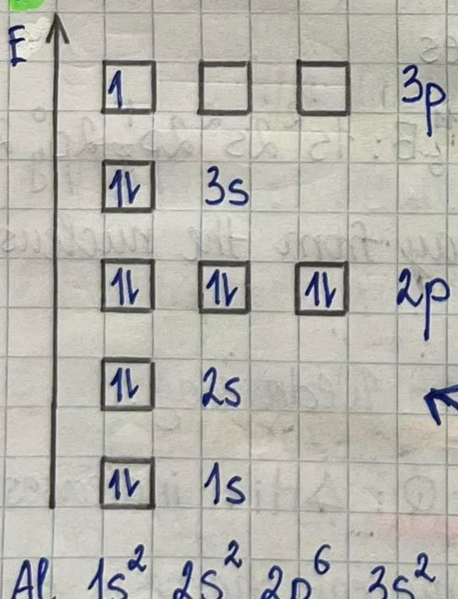

quantum level
⇓
electron shell

Al $1s^2 2s^2 2p^6 3s^2 3p_x^1 3p_y^0 3p_z^0$