Atomic Structure

Atoms contain electron, proton and neutron.

Sub-atomic particles	Symbol	position	relative charge	Relative mass
Electron	e^-	energy shell	-1	$\frac{1}{1836}$
Proton	p	Nucleus	+1	1
Neutron	n	Nucleus	0	1

Atomic number / proton number:

Total number of protons in the nucleus of an atom.

Mass number / nucleon number:

Total number of protons and neutrons in the nucleus of an atom.

Neutron number = Mass number − Atomic Number.

- Neutral atoms contain same number of protons and electrons.

* Ions have unequal number of electrons and protons.

Ion : Cation or Anion.

Cation : 1. Positively charged ions are called cations.
2. Cations are formed due to the loss of electrons.
3. Cations have more protons than electrons.
4. Number of positive charge on the cation indicates the number of electrons that are donated.

Anion : 1. Negatively charged ions are called ions.
2. Anions are formed due to the gain of electrons.
3. Anions have more electrons than protons.
4. Number of negative charge on the anion indicates the number of electrons that are gained.

Ion	No. of electrons	No. of protons	No. of neutrons.
HCO_3^-	32	31	30
N_3^-	22	21	21
H_3O^+	10	11	8
NH_4^+	10	11	7
SO_4^{2-}	50	48	48

Isoelectronic ion

Ions which have identical electronic / identical electronic configuration are called isoelectronic ion.

Na^+ Mg^{2+} Al^{3+} N^{3-} O^{2-} F^-

Isoelectronic cation

Cations which have identical number of electrons are called isoelectronic cations.

eg. Na^+ Mg^{2+} Al^{3+}

Isoelectronic anions

Anions which have identical number of electrons are called isoelectronic anions.

eg. N^{3-} O^{2-} F^{-}

* Of Cations, The higher charge has the smallest atomic radius.
* Of Anions, The higher charge has the longest atomic radius.

Electronic Configuration

- The arrangement of electrons at the different energy shells in an atom is called electronic configuration.

- Maximum numbers of electrons in an energy shell = $2n^2$

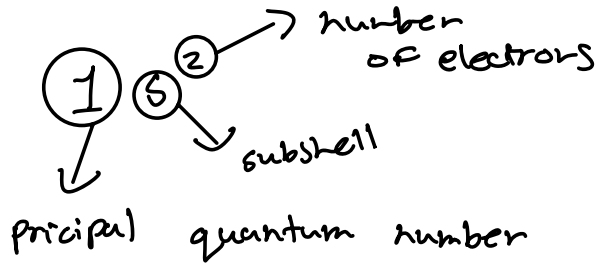
  $n = 1, 2, 3, 4, 5$

Principal quantum number	Maximum number of electrons
$n = 1$	$2 \times (1)^2 = 2$
$n = 2$	$2 \times (2)^2 = 8$
$n = 3$	$2 \times (3)^2 = 18$
$n = 4$	$2 \times (4)^2 = 32$

Value of n	Sub shell
$n = 1$	s
$n = 2$	s, p
$n = 3$	s, p, d
$n = 4$	s, p, d, f

Sub shell	Maximum number of electrons
s	2
p	6
d	10
f	14

Sub shell	number of orbitals
s	1
p	3
d	5
f	7



H	$1s^1$	Na	$1s^2 2s^2 2p^6 3s^1$
He	$1s^2$	Mg	$1s^2 2s^2 2p^6 3s^2$
Li	$1s^2 2s^1$	Al	$1s^2 2s^2 2p^6 3s^2 3p^1$
Be	$1s^2 2s^2$	Si	$1s^2 2s^2 2p^6 3s^2 3p^2$
B	$1s^2 2s^2 2p^1$	P	$1s^2 2s^2 2p^6 3s^2 3p^3$
C	$1s^2 2s^2 2p^2$	S	$1s^2 2s^2 2p^6 3s^2 3p^4$
N	$1s^2 2s^2 2p^3$	Cl	$1s^2 2s^2 2p^6 3s^2 3p^5$
O	$1s^2 2s^2 2p^4$	Ar	$1s^2 2s^2 2p^6 3s^2 3p^6$
F	$1s^2 2s^2 2p^5$	K	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
Ne	$1s^2 2s^2 2p^6$	Ca	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

Sc $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$

Ti $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

V $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$

Cr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$

Mn $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$

Fe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

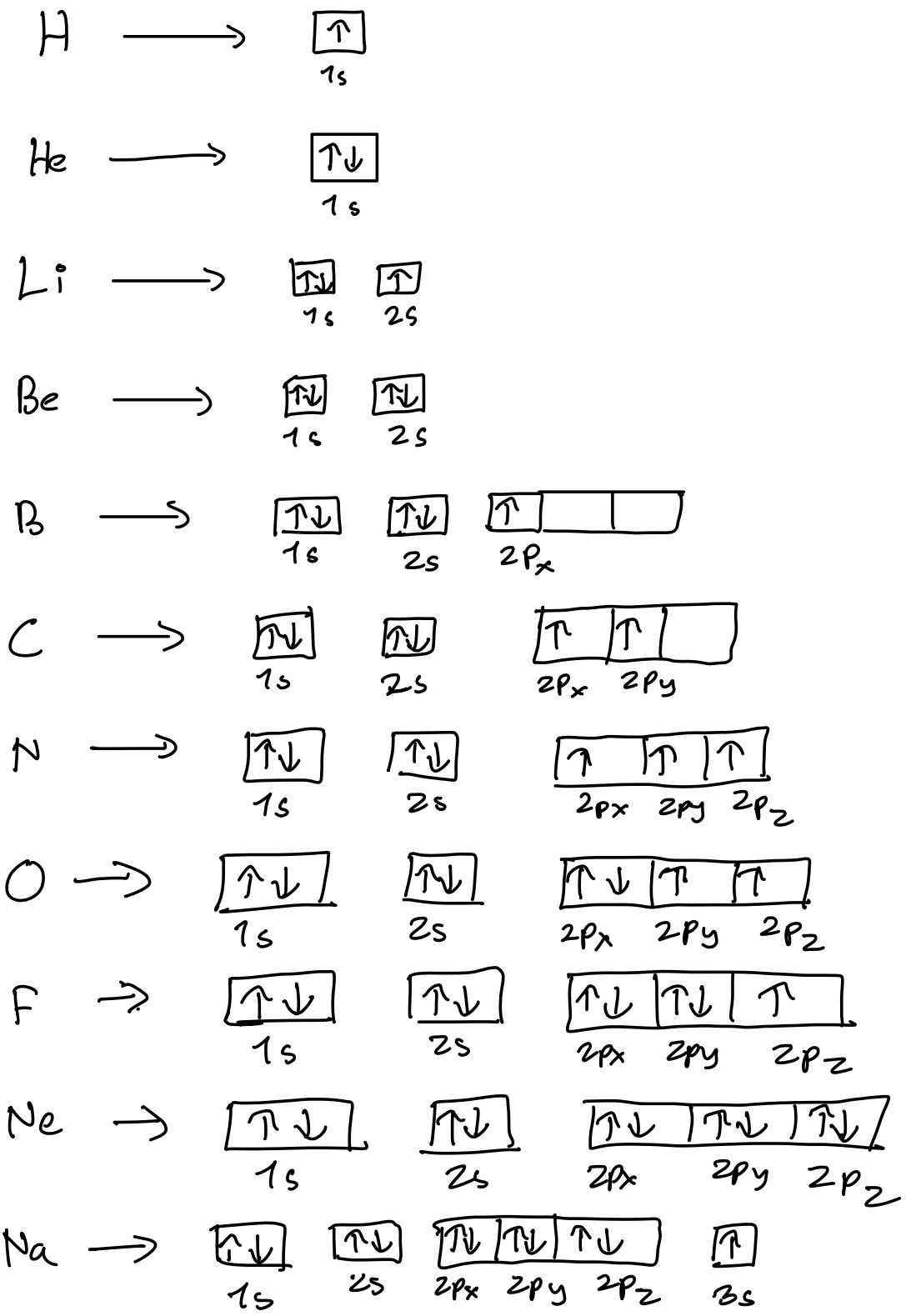
Co $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$

Ni $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$

Cu $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$

Zn $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$

*For d, sub shell, 5 and 10 electrons are very stable.


H
1s
He
1s
Li
1s
2s
Be
1s
2s
B
1s
2s
2px
C
1s
2s
2px
2py
N
1s
2s
2px
2py
2pz
O
1s
2s
2px
2py
2pz
F
1s
2s
2px
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Na
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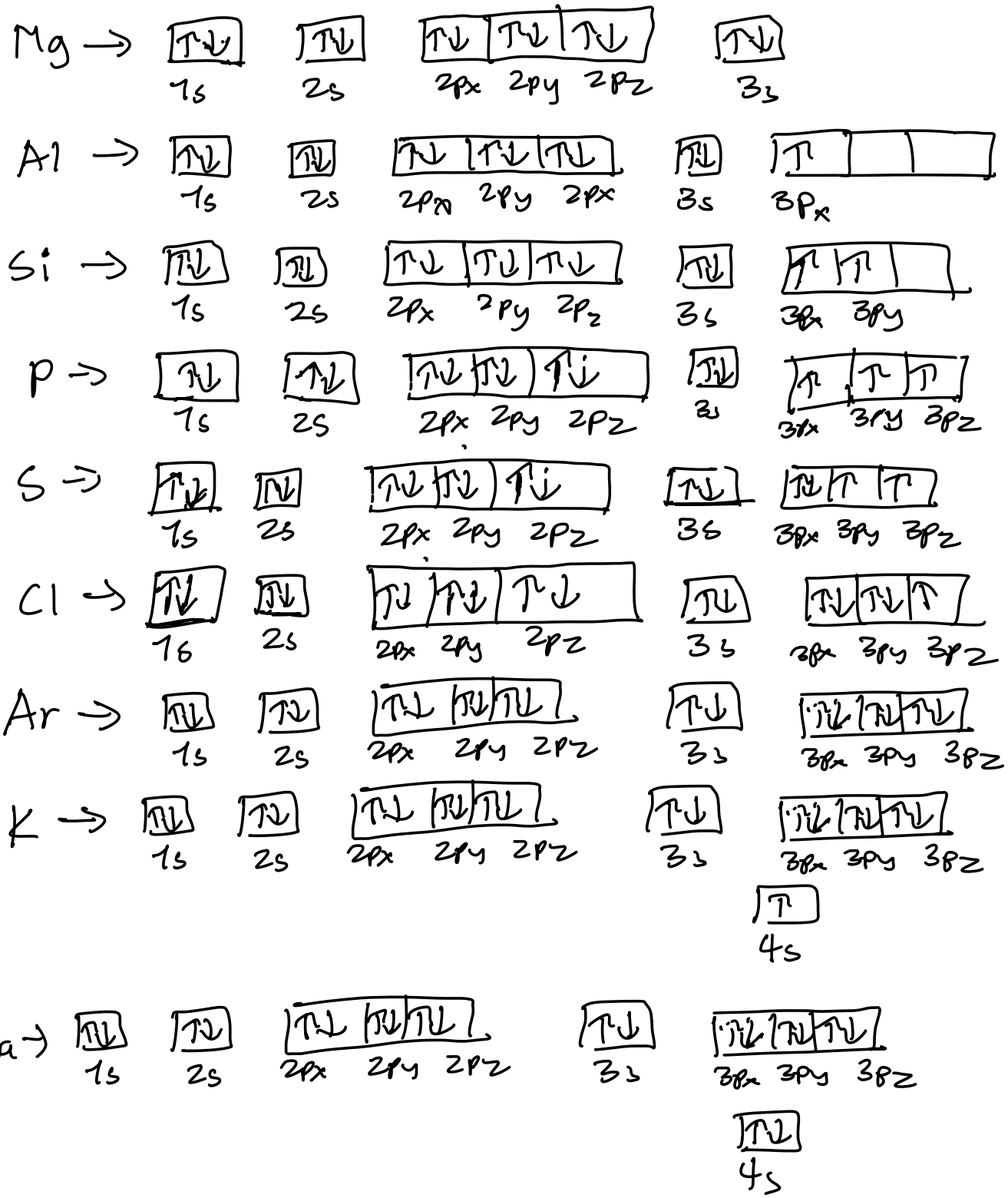
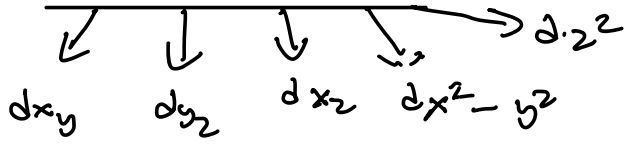
2s
2px
2py
2pz
3s


Mg →
1s 2s 2px 2py 2pz 3s
Al →
1s 2s 2px 2py 2px 3s 3px
Si →
1s 2s 2px 2py 2pz 3s 3px 3py
P →
1s 2s 2px 2py 2pz 3s 3px 3py 3pz
S →
1s 2s 2px 2py 2pz 3s 3px 3py 3pz
Cl →
1s 2s 2px 2py 2pz 3s 3px 3py 3pz
Ar →
1s 2s 2px 2py 2pz 3s 3px 3py 3pz
K →
1s 2s 2px 2py 2pz 3s 3px 3py 3pz
4s
Ca →
1s 2s 2px 2py 2pz 3s 3px 3py 3pz
4s

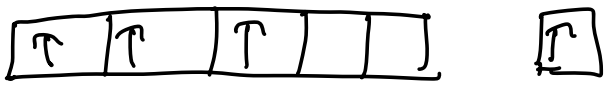
* Five d orbitals



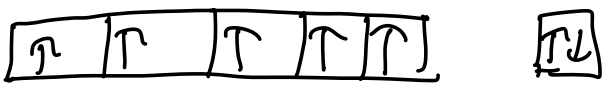
Sc → [Ar]

Ti → [Ar]

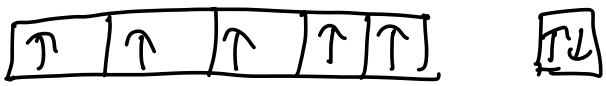
V → [Ar]



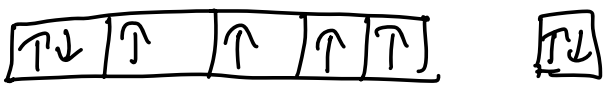
Cr → [Ar]



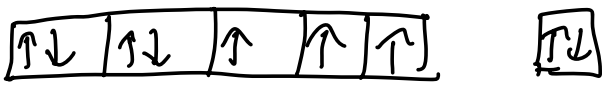
Mn → [Ar]



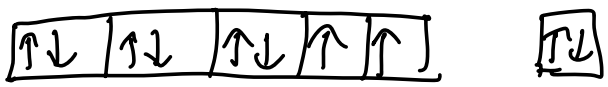
Fe → [Ar]



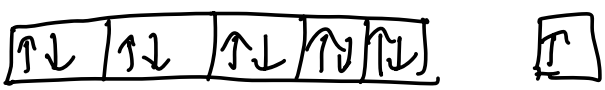
Co → [Ar]



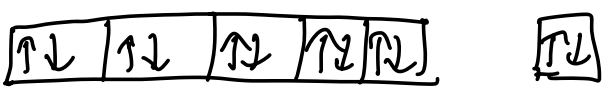
Ni → [Ar]

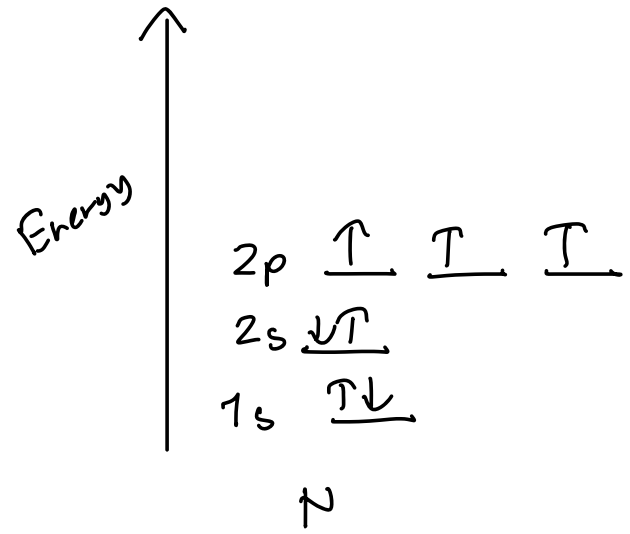


Cu → [Ar]

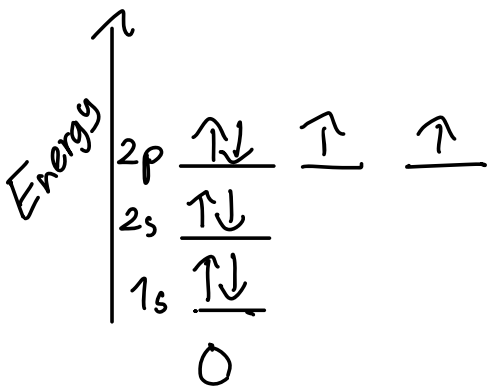


Zn → [Ar]

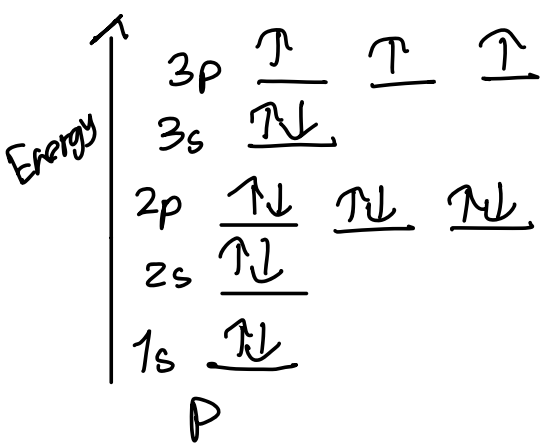



Energy
2p
2s
1s

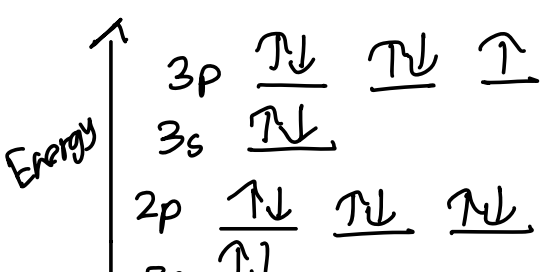
N

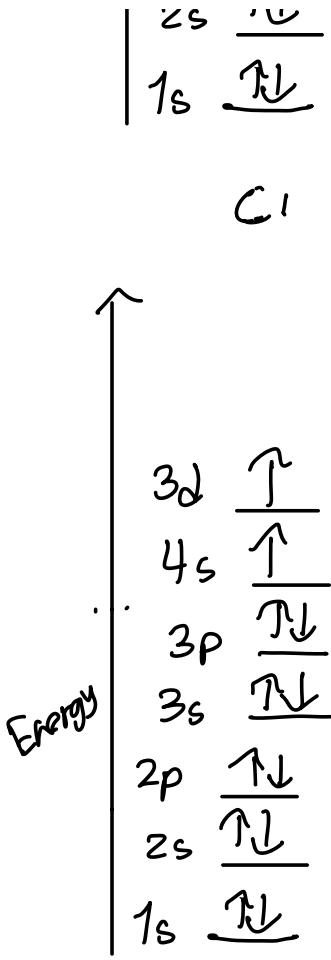

Energy
2p
2s
1s

O

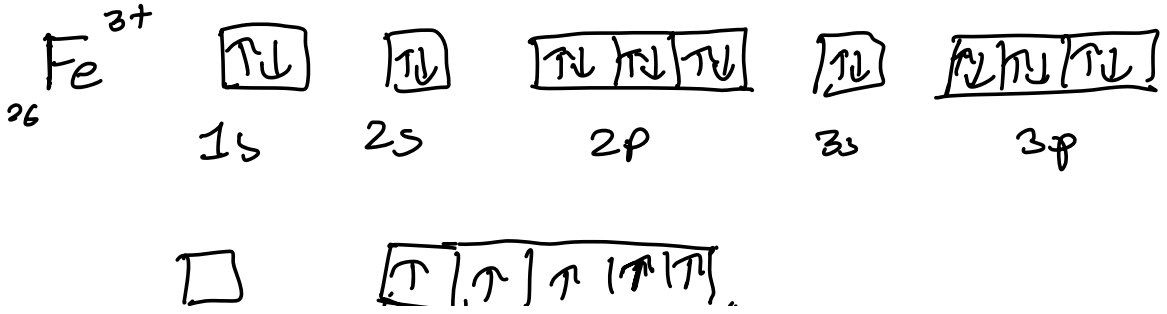

Energy
3p
3s
2p
2s
1s

P

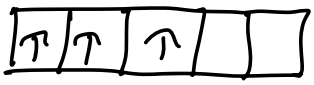

Energy
3p
3s
2p



* During the formation of positively charged ions, 3d block elements will donate electrons at first from the 4s.



4s 3d

Cr^{2+} [Ar] 

Cu^{2+} [Ar] 

Ionisation Energy (IE)

The amount of energy required when one electron is removed from each atom in one mole of gaseous atoms.

$$X_{(g)} \rightarrow X^{+}_{(g)} + e^{-}$$

Energy is required to remove 1 mole of electrons from 1 mole gaseous atoms to make 1 mole of +1 gaseous ions is called first ionisation energy.

Second ionisation energy

$$X^{+}_{(g)} \rightarrow X^{2+}_{(g)} + e^{-}$$

Energy is required to remove 1 mole electrons from 1 mole +1 gaseous ions to make 1 mole +2 gaseous ion is called second ionisation energy.

Gr-1 element

$Li_{(g)} \longrightarrow Li^{+}_{(g)} + e^{-} \quad \Delta H_{i_1} = 519 \text{ KJ mol}^{-1}$

$Na_{(g)} \rightarrow Na^{+}_{(g)} + e^{-} \quad \Delta H_{i_1} = 494 \text{ KJ mol}^{-1}$

$K_{(g)} \rightarrow K^{+}_{(g)} + e^{-} \quad \Delta H_{i_1} = 418 \text{ KJ mol}^{-1}$

$Rb_{(g)} \rightarrow Rb^{+}_{(g)} + e^{-} \quad \Delta H_{i_1} = 403 \text{ KJ mol}^{-}$

$Be_{(g)} \rightarrow Be^{+}_{(g)} + e^{-} \quad \Delta H_{i_1} = 900 \text{ KJ mol}^{-1}$

$Mg_{(g)} \rightarrow Mg^{+}_{(g)} + e^{-} \quad \Delta H_{i_1} = 736 \text{ KJ mol}^{-1}$

$Ca_{(g)} \rightarrow Ca^{+}_{(g)} + e^{-} \quad \Delta H_{i_1} = 590 \text{ KJ mol}^{-1}$

Second ionisation energy

Gr 1

$Li^+_{(g)} \rightarrow Li^{2+}_{(g)} + e^- \quad \Delta H_{i_2} = 7300 \text{ KJ mol}^{-1}$

$Na^+_{(g)} \rightarrow Na^{2+}_{(g)} + e^- \quad \Delta H_{i_2} = 4560 \text{ KJ mol}^{-1}$

$K^+_{(g)} \rightarrow K^{2+}_{(g)} + e^- \quad \Delta H_{i_2} = 3070 \text{ KJ mol}^{-1}$

Second ionisation energy Gr-2

$Be^+_{(g)} \rightarrow Be^{2+}_{(g)} + e^- \quad \Delta H_{i_2} = 1760 \text{ KJ mol}^{-1}$

$Mg^+_{(g)} \rightarrow Mg^{2+}_{(g)} + e^- \quad \Delta H_{i_2} = 1450 \text{ KJ mol}^{-1}$

$Ca^+_{(g)} \rightarrow Ca^{2+}_{(g)} + e^- \quad \Delta H_{i_2} = 1150 \text{ KJ mol}^{-1}$

Gr-1 elements

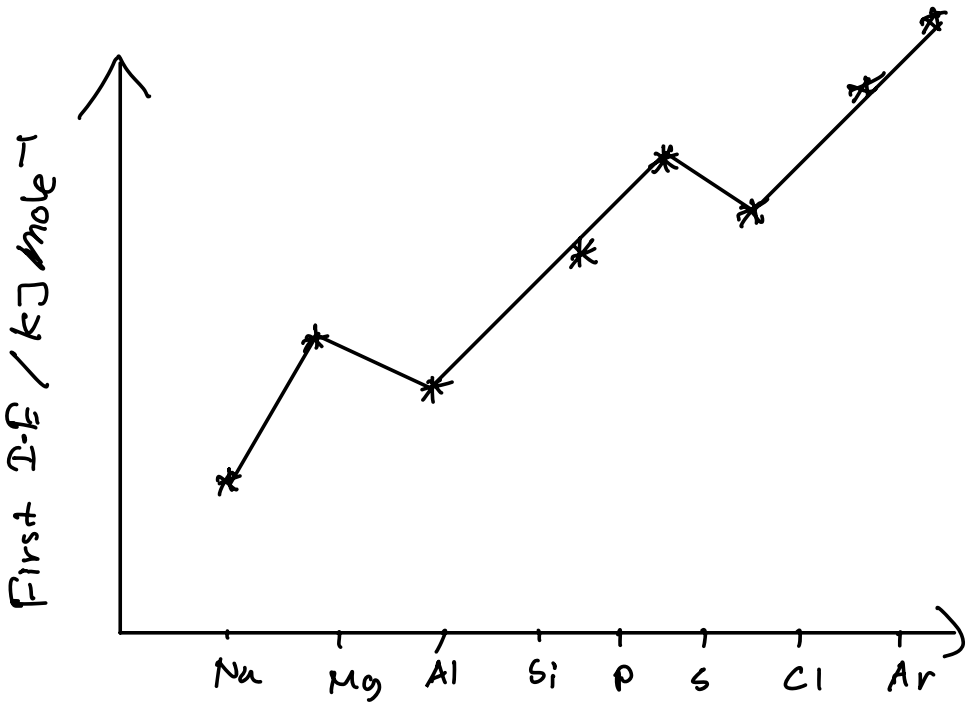
Li
Na
K
Rb
Cs

- Ionisation energy decreases
- number of energy shells increase
- electrons are added to the new energy shell
- ~~Atomic~~ radius increases.
- ~~Shielding~~ effect increases.
- ~~Attraction~~ between nucleus and the outermost shell electron decreases.
- ~~Despite~~ the increase of nuclear charge, less energy is needed to remove the electrons.

Third period elements

Na Mg Al Si P S Cl Ar →

- Ionisation energy increases.
- Electrons are added to the same energy shell.
- Number of energy shell identical
- Nuclear charge increases
- shielding effect almost constant
- size of the atoms decreases.
- Nuclear attraction increases.
- Attraction between nucleus and outermost shell electron increases.



First ionisation energy of aluminium is less than magnesium

Mg → $1s^2\ 2s^2\ 2p^6\ 3s^2$

Al → $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

- In magnesium, outer electrons in 3s orbital.
- 3p oribital electron is higher energy level than the 3s orbital.
- 3p electron is further away from the nucleus than the 3s orbital.
- 3p orbital electron is more shielded than the 3s orbital electron.
- less energy is needed to remove electron from the orbital.

Phosphorous has higher first ionisation energy than sulfur

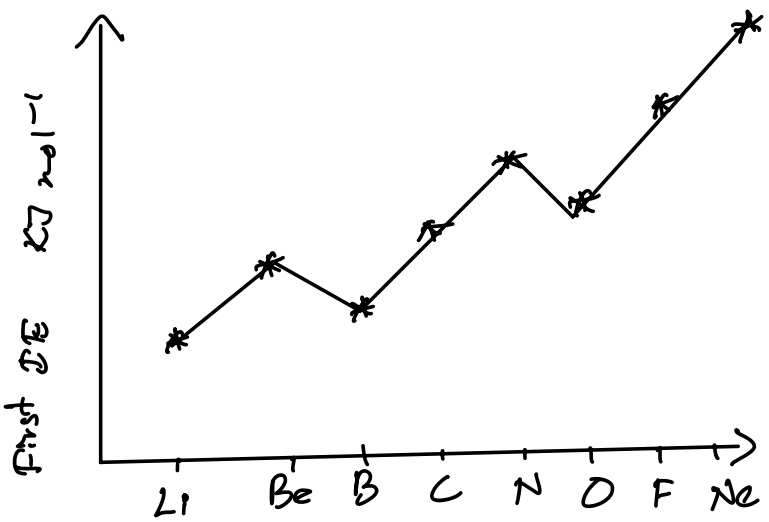
^{15}P ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑ ↑
1s 2s 2p 3s 3p

^{16}S ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑ ↑
1s 2s 2p 3s 3p

① In phosphorous 3p orbital are singly filled.

② In sulfur one of the 3p orbitals has a pair of electrons and repulsion between paired electron.

Second period electrons

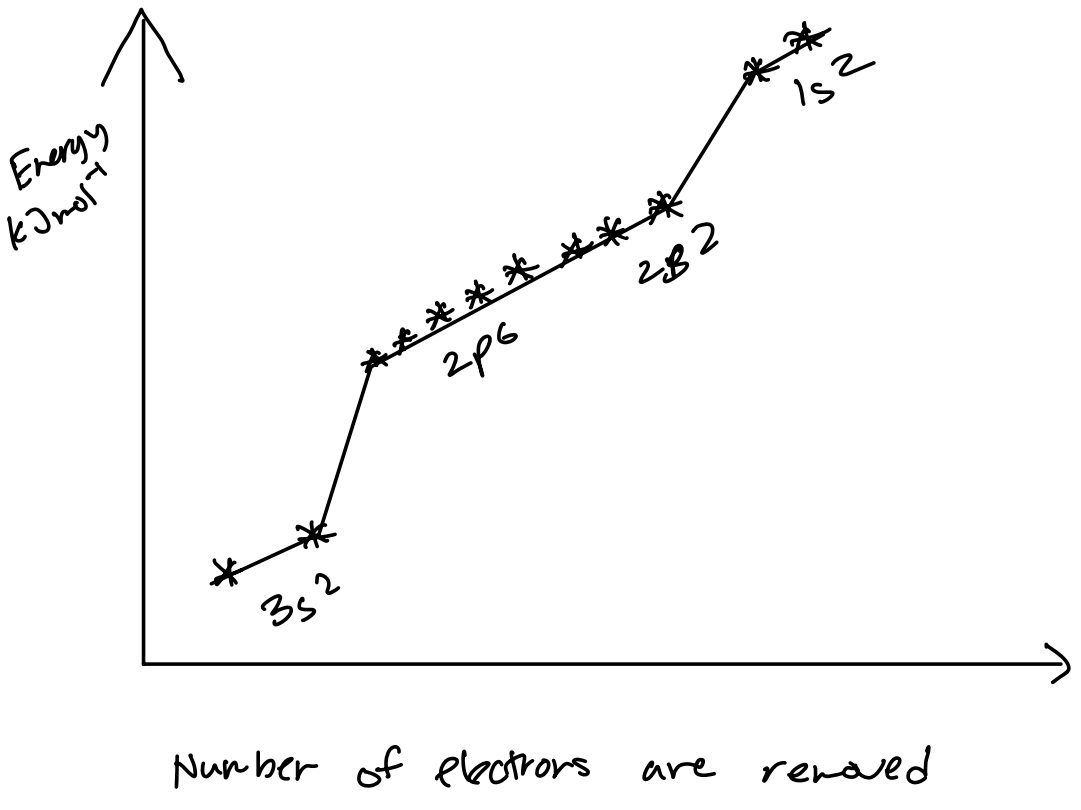


* Be has it's outer shell electron at 2s but B has it's outer shell electron at 2p orbital. 2p orbital is further from the nucleus than 2s orbital. There is less attraction with the nucleus of the 2p electron than the 2s electron because of increased shielding effect. So lesser energy is needed to remove the electron from 2p orbital than 2s orbital.

* The 2p orbital of nitrogen is singly filled but the 2p orbital of oxygen has a a pair of electrons so there is spin pair repulsion between the paired electrons. As a result, less energy is needed to remove the electron from oxygen than nitrogen.

Successive ionisation energy

- Successive ionisation energy data can be used to determine group number of an unknown element.
- Number of electrons are removed before before the first large energy gap indicates number of electrons in the outermost shell.
- Number of electrons in the outermost shell indicates the group number.



Unknown element X

5th	6th	7th	8th
7012	8496	27107	31671

- Group number of X is 6
- Before the first large energy gap, six electrons are removed.
- Outermost shell contains 6 electrons.

Effective nuclear charge

- Effective nuclear charge is the net positive charge experienced by an electron in a poly electronic atom.

- In any period, noble gas has the highest ionisation energy due to the highest nuclear charge.

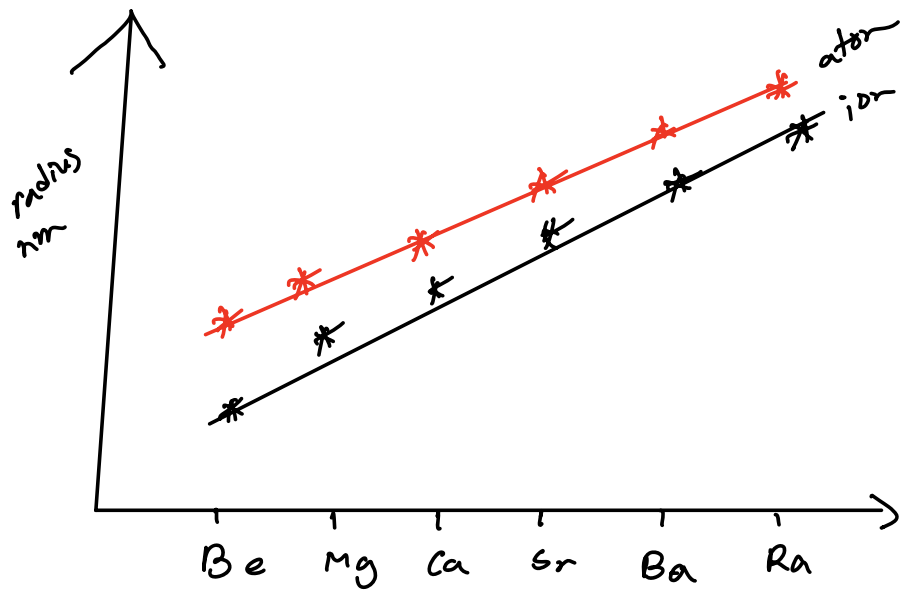
⊖ From Na to Si, the ionic radii are less than the atomic radii.

⊖ Ions of Na to Si (Na^+, Mg^{2+}, Al^{3+}, Si^{4+}) have lost outer electrons / outer shell.

⊖ Atoms have one more energy shells than corresponding ion.

⊖ Effective nuclear charge is greater for ions.

Gr-2 atom and Gr-2 ion



⊖ Atomic radius down the group increases because the number of electron shells increases.

- Ionic radius down the group increase because number of electron shells increase.
- Increased distance of outer shell electrons from the nucleus.
- Increased shielding result in weaker nuclear attraction.

Radius of the atom is greater than the corresponding ion.

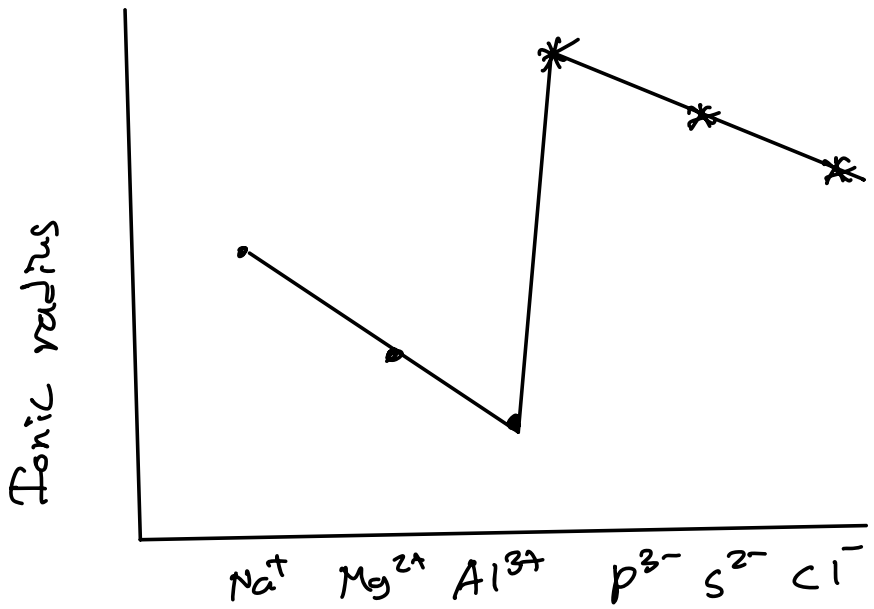
- Atom has one more shell than the corresponding ion.
- Atom loses electron to form ions.
- Effective nuclear charge in ion is greater.

Isoelectronic Cation

Na^+ Mg^{2+} Al^{3+}

Iso electronic Anion

P^{3-} S^{2-} Cl^{-}



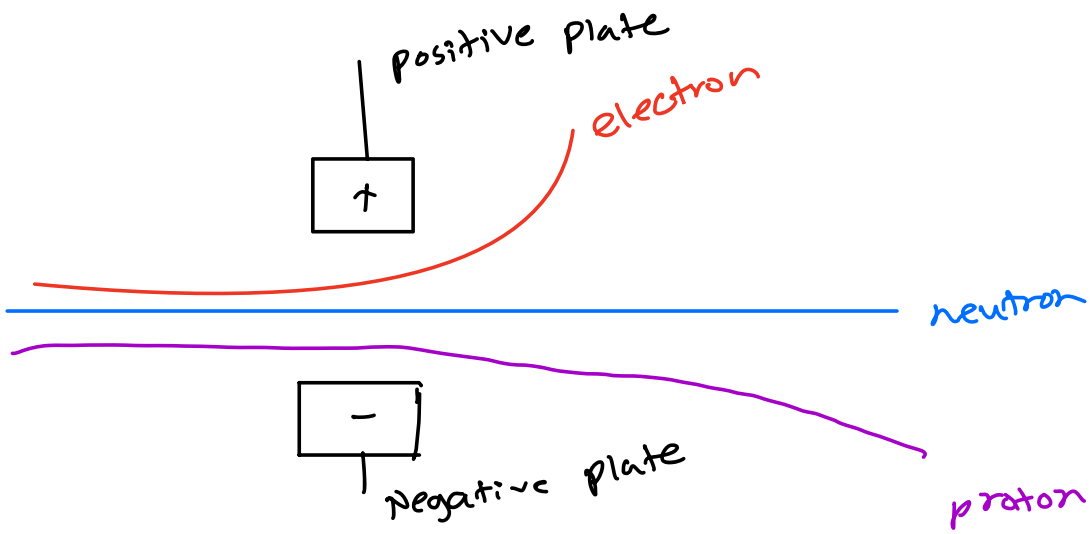
From Na^{+} to Al^{3+} ionic radius decrease

- Number of energy shells identical.
- Number of electrons identical.
- Number of protons increase from Na^{+} to Al^{3+}
- Nuclear charge increases.
- Nuclear attraction increase.

From P^{3-} to Cl^- ionic radius decrease

- The anions are larger than their original atoms.
- P^{3-} ion has three more electrons than protons.
- P^{3-} ion has weakest nuclear attraction.
- P^{3-} ion has largest ionic radius.

Subatomic particles in an electric field



⊖ protons are positively charged and will be deflected away from the the positive plate and towards the negative plate.

⊖ Neutrons have no charge and will continue moving in a straight line.

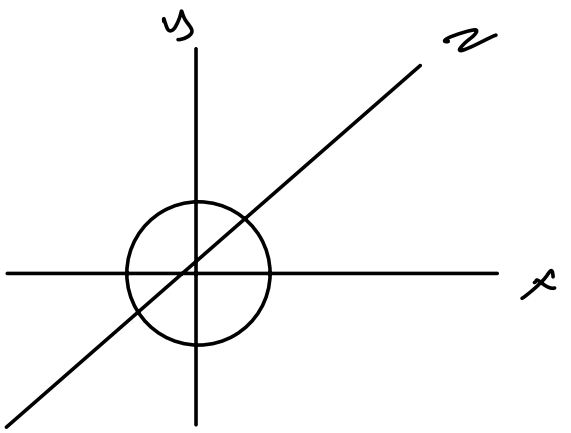
⊖ Electrons are negatively charged and will be deflected away from the negative plate and towards the positive plate.

*** Beam of charged particles are deflected by an electric field. The angle of deflection of a particle is proportional to its charge/mass ratio.

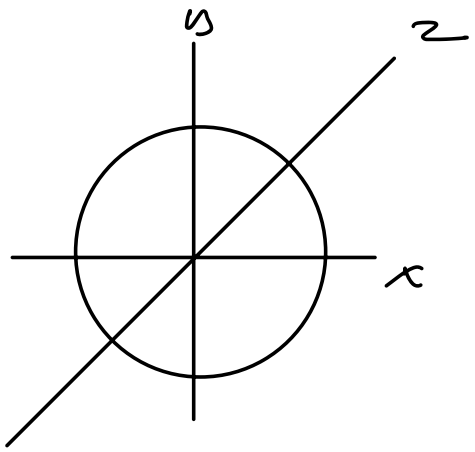
In an experiment, protons are deflected by an angle of $+15°$.

In another experiment under identical conditions $^2H^-$ ions are deflected by an angle of $-7.5°$.

S orbital

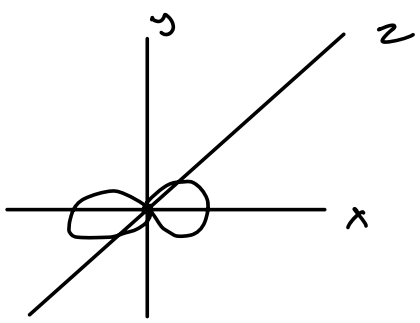


1s

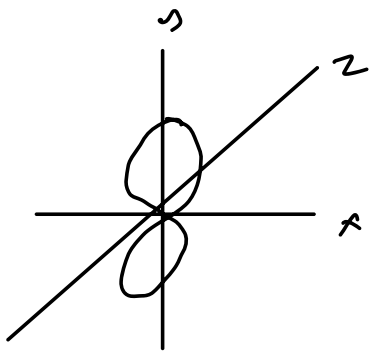


2s

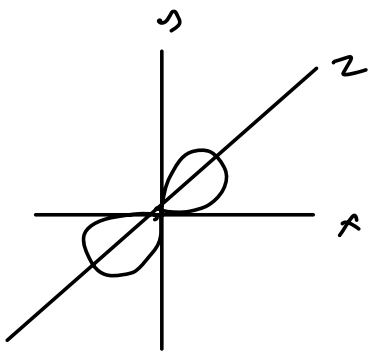
P orbital



P_x



P_y



P_z