General Chemistry

Periodic Table

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Chapter Description

- Expected Outcome:

  At the end of the lecture, the students should be able to understand and solve the problems regarding on the periodic table, representative and transition elements.

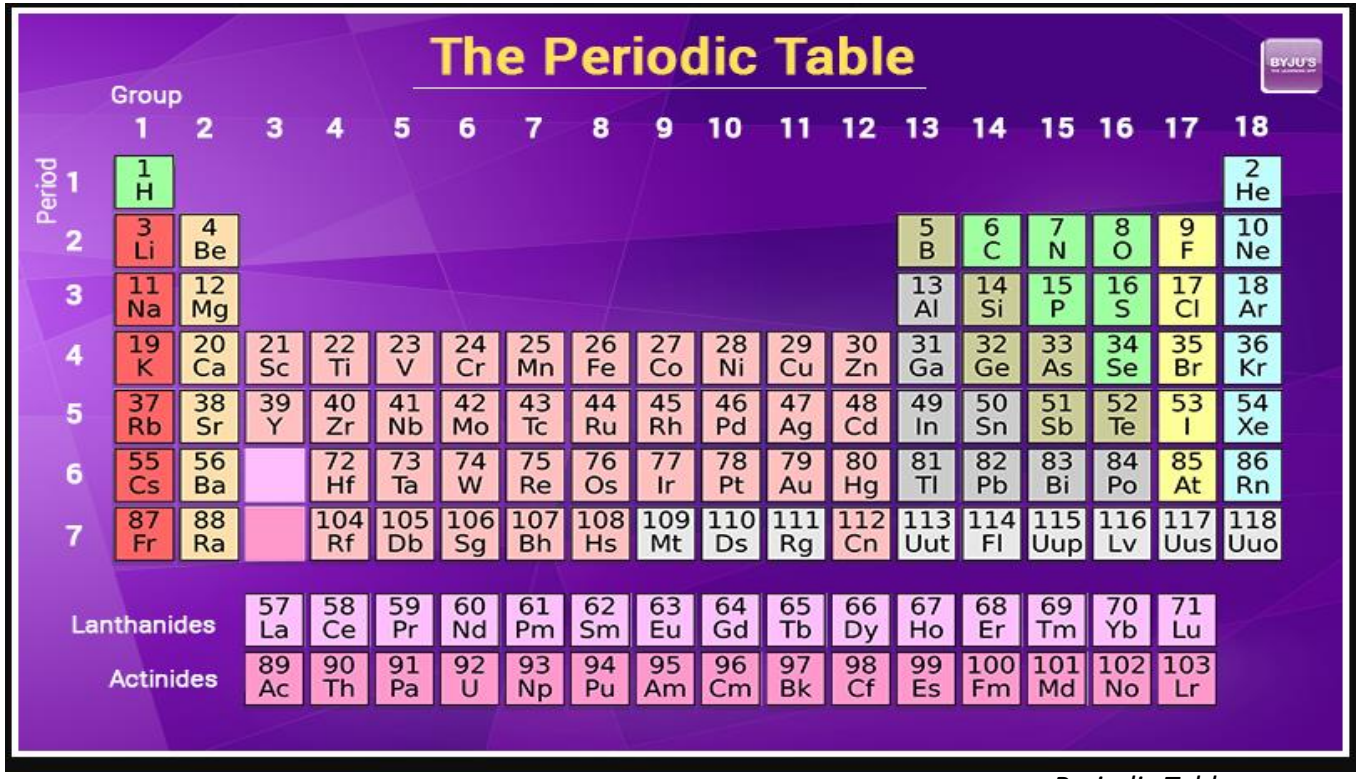
- Reference:
  - Chemistry for matriculation semester 1, Tan Yin Toon, Sheila Shamuganathan. Companion website.

Content

- Representative elements (Group IA-VIIA)
- Transition elements (IB-VIIB)

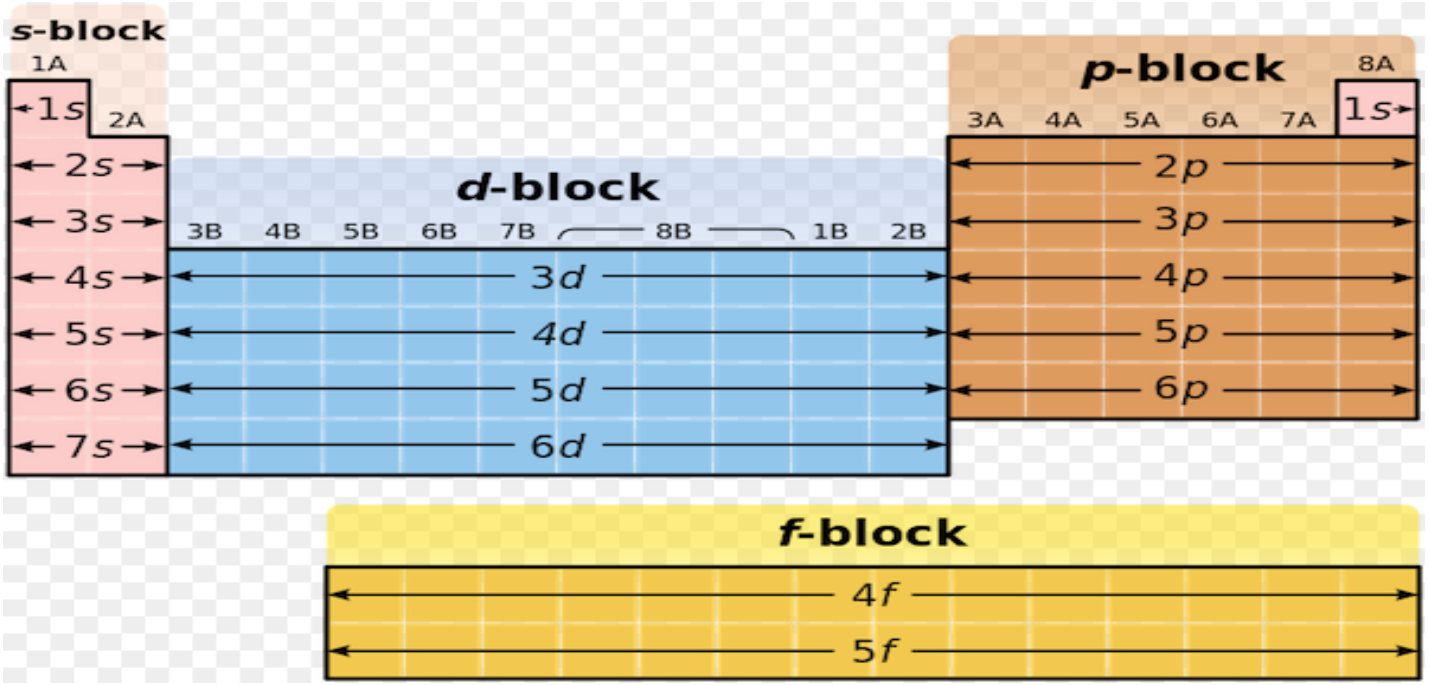
Periodic table

- Picture source: http://s3-ap-southeast-1.amazonaws.com/subscriber.images/chemistry/2016/04/12130832/Periodic-Table1.png



Periodic table

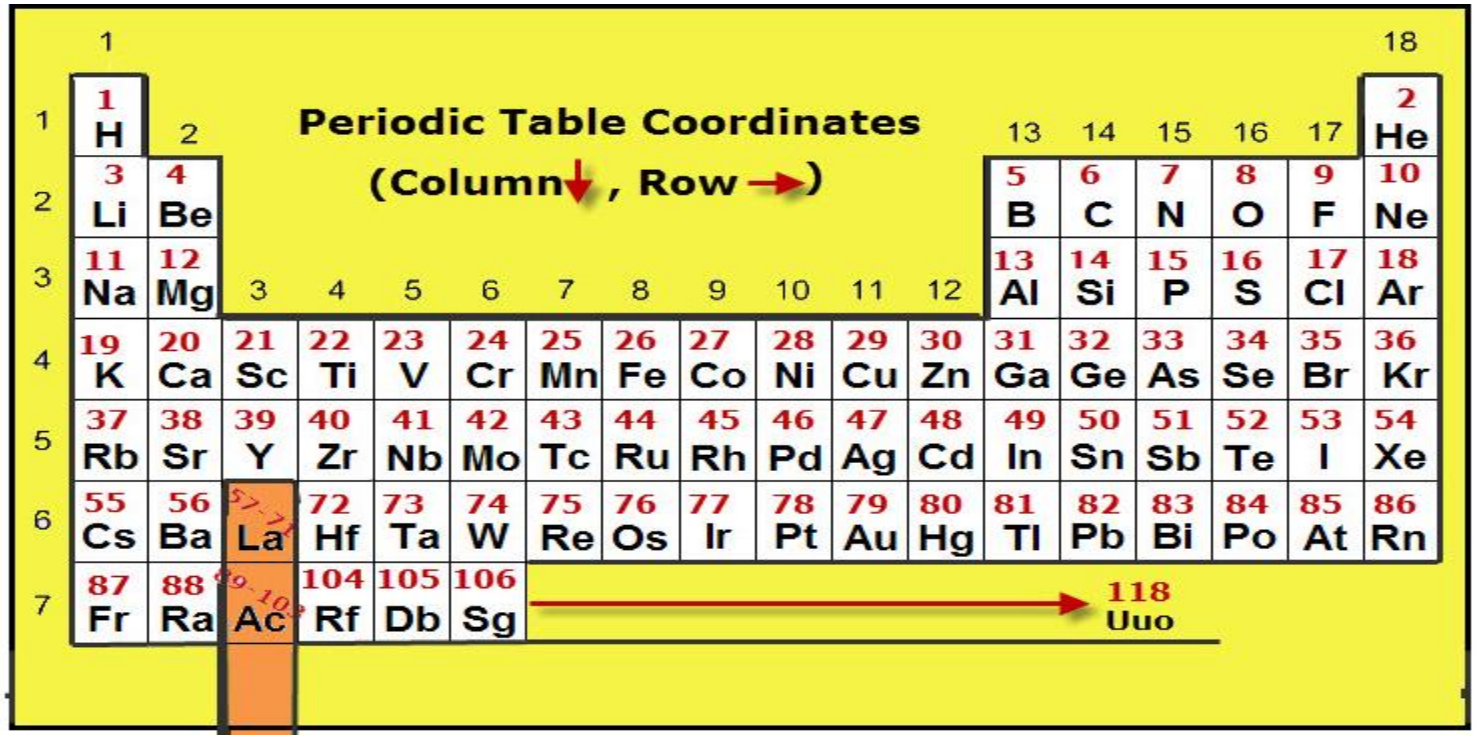
- Consist of 4 main block, s,p,d,f



- Picture source: http://study.com/cimages/multimages/16/800px-periodic_table_structure.svg.png

Periodic table number

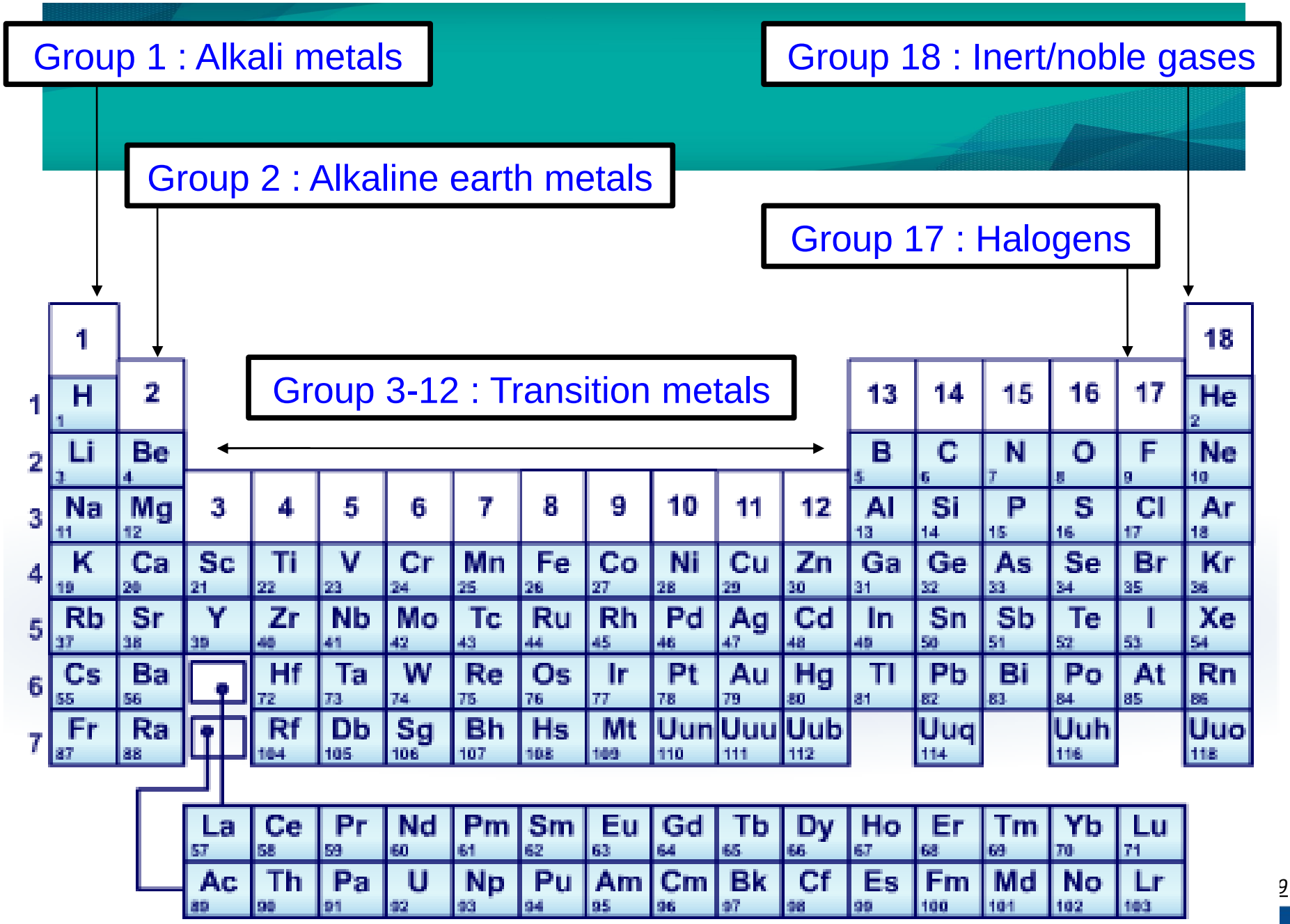
- The groups are numbered from 1 to 18



- Picture source: http://scienceprojectideasforkids.com/wp-content/uploads/2011/11/Periodic-Table-symbols-atomic-numbers.jpg

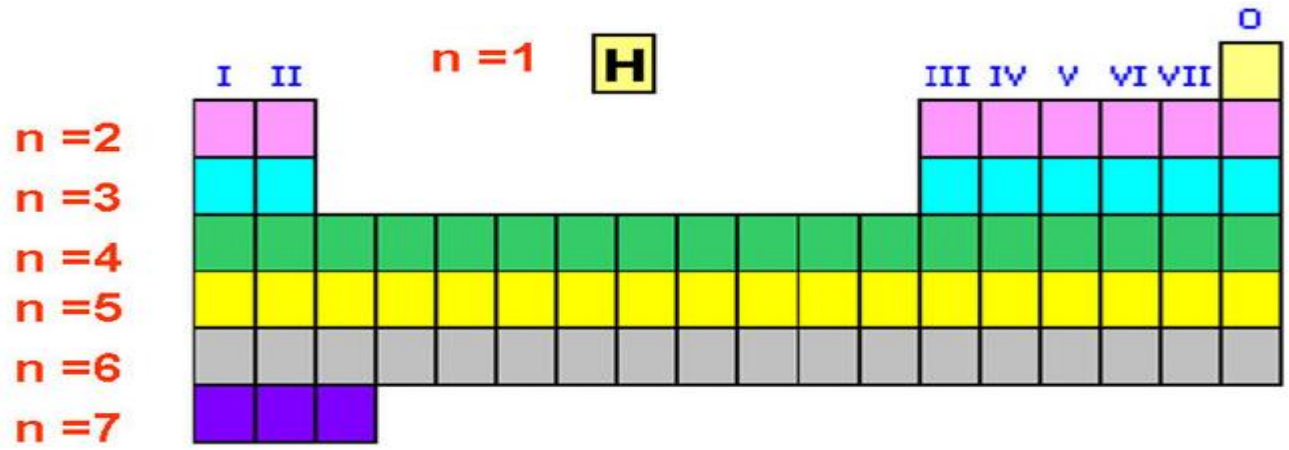
- Elements in the same group have the same number of valence electrons.

Elements	Li (Lithium)	Al (Aluminium)	V (Vanadium)
Electronic configuration	$1s^2\ 2s^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$
Valence electron	1	3	5
Group	Group 1	Group 13	Group 5


Group 1 : Alkali metals
Group 18 : Inert/noble gases
Group 2 : Alkaline earth metals
Group 17 : Halogens
Group 3-12 : Transition metals
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
H 1
He 2
Li 3
Be 4
B 5
C 6
N 7
O 8
F 9
Ne 10
Na 11
Mg 12
Al 13
Si 14
P 15
S 16
Cl 17
Ar 18
K 19
Ca 20
Sc 21
Ti 22
V 23
Cr 24
Mn 25
Fe 26
Co 27
Ni 28
Cu 29
Zn 30
Ga 31
Ge 32
As 33
Se 34
Br 35
Kr 36
Rb 37
Sr 38
Y 39
Zr 40
Nb 41
Mo 42
Tc 43
Ru 44
Rh 45
Pd 46
Ag 47
Cd 48
In 49
Sn 50
Sb 51
Te 52
I 53
Xe 54
Cs 55
Ba 56
Hf 72
Ta 73
W 74
Re 75
Os 76
Ir 77
Pt 78
Au 79
Hg 80
Tl 81
Pb 82
Bi 83
Po 84
At 85
Rn 86
Fr 87
Ra 88
Rf 104
Db 105
Sg 106
Bh 107
Hs 108
Mt 109
Uun 110
Uuu 111
Uub 112
Uuq 114
Uuh 116
Uuo 118
La 57
Ce 58
Pr 59
Nd 60
Pm 61
Sm 62
Eu 63
Gd 64
Tb 65
Dy 66
Ho 67
Er 68
Tm 69
Yb 70
Lu 71
Ac 89
Th 90
Pa 91
U 92
Np 93
Pu 94
Am 95
Cm 96
Bk 97
Cf 98
Es 99
Fm 100
Md 101
No 102
Lr 103

Period number

- The period are numbered from 1 to 7



Horizontal rows of elements = period = no. of occupied e⁻ shells (n)

- Picture source: https://mypchem.wikispaces.com/file/view/PT5.png/241757599/PT5.png

Period number

Elements	Li (Lithium)	Al (Aluminium)	V (Vanadium)
Electronic configuration	$1s^2\ 2s^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$
Higher Principal Quantum Number	2	3	4
Period	Period 2	Period 3	Period 4

Period number

Elements	Li (Lithium)	Al (Aluminium)	V (Vanadium)
Electronic configuration	$1s^2\ 2s^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$
Higher Principal Quantum Number	2	3	4
Period	Period 2	Period 3	Period 4

d block- transition element

- Also called transition elements
- Metals
- No extreme variability

Elements of d-block	Co (Cobalt)	Tc (Technetium)	Au (Gold)
Electronic configuration	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^6\ 5s^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6\ 4f^{14}\ 5d^{10}\ 6s^1$
Outermost electrons	2 electrons	1 electron	1 electron
Valence electrons	9 electrons	7 electrons	11 electrons
Inner electrons (electrons in inner shell)	25 electrons	42 electrons	78 electrons

s block

- metals
- Valence electron is maximum of 2 electron

	s
Number of valence electrons	1-2 electron
Orbitals of valence electrons	s-orbitals
Configuration of valence electrons	ns^1 to ns^2
Group	Group 1 & 2
Example	$_{11}Na$: $1s^2\ 2s^2\ 2p^6\ 3s^1$ $_{20}Ca$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

p block

- Maximum of 6 electron in the orbital

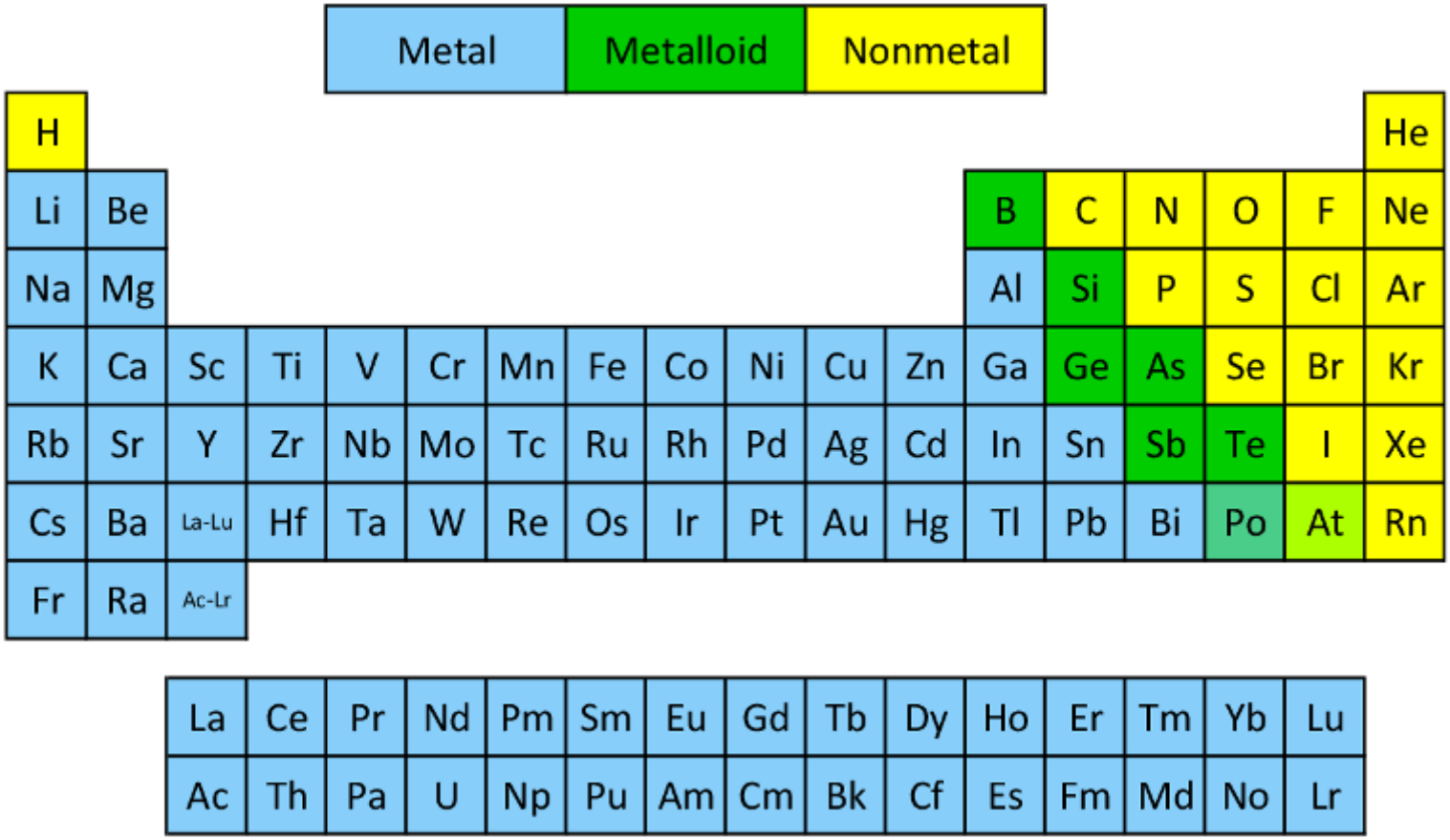
	p
Number of valence electrons	3-8 electrons
Orbitals of valence electrons	s and p-orbitals
Configuration of valence electrons	$ns^2\ np^1$ to $ns^2\ np^6$
Group	Group 13 – 18
Example	$_{13}Al$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ $_{14}Si$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

f block

- Maximum of 6 electron in the orbital

	f
Number of valence electrons	3-17 electrons
Orbitals of valence electrons	f-orbitals
Configuration of valence electrons	$(n-1)d^{1}\ ns^{2}$ to $(n-2)f^{14}(n-1)d^{1\ or\ 2}\ ns^{2}$
Group	Lanthanides & Actinides
Example	The filling of valences electron happens in the subshell of 4f and 5f.

Metal, non metal, metalloid



- Picture source: http://www.nemoquiz.com/wp-content/uploads/2014/07/Periodic-Table-MetalNonmetalSmall.png

Position of an element

- The position of an element in the periodic table can be deduced from its outermost electronic configuration.

Atomic radius

- Determined by
- 1- effective nuclear charge- Zeff- positive charge felt by an electron

$$Z_{eff} = Z - S$$

Z = no. of proton
S = no. of electrons filled at the inner orbital/ number of inner or core electrons

- 2- screening effect- aka shielding effect- caused by mutual repulsion between inner and outer shell electron

Across a period

- number of protons increase
  (more protons are added to the nucleus, hence nuclear charge also increase)

- Zeff increases

- outer electrons are pulled closer to nucleus.

- nucleus-electron attraction increases.

- atomic radius becomes smaller.

- atomic radius generally decrease across a period from left to right.

Crossing down group

- proton number increase and nuclear charge also increase.

- outer electrons enter new energy levels.

- principal quantum number, n of the valence electrons increase.

- more inner electrons.

- inner electrons shield the outer electrons effectively.
  Screening effect increase.

- Zeff is not significant.

- atomic radius generally increase in a group from top to bottom.

Atomic and ionic radius

Positive ions (cations)

- smaller than their neutral atoms.

- when electrons are removed from an atom, repulsion between electrons decrease.

- number of proton remain, nuclear charge remain the same.

- remaining electrons are pulled closer towards the nucleus.

- electron cloud shrink.

- cation is smaller than its atom.

COMPARISON OF ATOMIC RADIUS AND ITS IONIC RADIUS

Negative ions (anions)

- always larger than their neutral atoms.

- has more electrons as it gains electron during formation.

- when electrons are added to an atom, repulsion between electrons increase.

- outer orbital expands, nuclear charge remain the same.

- electrons cloud enlarge.

- anions is larger than its atom.

Isoelectronic

Group of atoms or ions with same electronic configuration.

- Across the period, sizes of cations and anions decrease due to the increase of Zeff.

- Ionic radii of $Na^{+} > Mg^{2+} > Al^{3+} > Si^{4+}$

They are isoelectronic (10 e) because their electronic configurations are the same : $1s^2\ 2s^2\ 2p^6$

Ions	Electron Configuration	Ionic Radii
Na^+	$1s^2\ 2s^2\ 2p^6$ or Ne	95
Mg^{2+}	$1s^2\ 2s^2\ 2p^6$ or Ne	65
Al^{3+}	$1s^2\ 2s^2\ 2p^6$ or Ne	50
N^{3-}	$1s^2\ 2s^2\ 2p^6$ or Ne	171
O^{2-}	$1s^2\ 2s^2\ 2p^6$ or Ne	140
F^-	$1s^2\ 2s^2\ 2p^6$ or Ne	136

3rd period

2nd period

Na^+, Mg^{2+}, Al^{3+}, F^-, O^{2-}, and N^{3-} are all isoelectronic with Ne

Ionic radii, period 2

Across the period 2, 

- Ionic radii of cations decrease from Li^{+} to B^{3+}

- Ionic radii of anions decrease from N^{3-} to F^{-}

- But the ionic radii increase from B^{3+} to N^{3-}

- The ionic radius decreases for metals forming cations, as the metals lose their outer electron orbitals. Thus the Zeff increases resulting the ionic radius to decrease.

- The ionic radius increases for nonmetals forming anions, as the effective nuclear charge decreases due to the number of electrons exceeding the number of protons.

Ionic radii, period 3

Across the period 3, 

- Ionic radii of cations decrease from Na^{+} to Si^{4+}

- Ionic radii of anions decrease from P^{3-} to Cl^{-}

- But the ionic radii increase from Si^{4+} to P^{3-}

The ionic radius decreases for metals forming cations, as the metals lose their outer electron orbitals. Thus the Zeff increases and causes the ionic radius to decrease.

- The ionic radius increases for nonmetals forming anions, as the effective nuclear charge decreases due to the number of electrons exceeding the number of protons.

- The increase in ionic size from Si^{4+} ($1s^2\ 2s^2\ 2p^6$) to P^{3-} ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$) is due to the presence of an additional electron shell.

-This causes an increase in screening effect.

- As a result, the ionic radius increases.

Cations

- The ionic radius decrease as follows:
  $Na^{+}>Mg^{2+}>Al^{3+}>Si^{4+}$

Ions	Electron configuration	No. of Electron	Z_{eff}	Ionic radii (pm)
Na^{+}	$1s^2\ 2s^2\ 2p^6$	10	11-2=+9	95
Mg^{2+}	$1s^2\ 2s^2\ 2p^6$	10	12-2=+10	65
Al^{3+}	$1s^2\ 2s^2\ 2p^6$	10	13-2=+11	50
Si^{4+}	$1s^2\ 2s^2\ 2p^6$	10	14-2=+12	41

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http://ocw.ump.edu.my/course/view.php?id=479

Anions

- The ionic radius decrease as follows: P^{3-} > S^{2-} > Cl^{-}

Ions	Electron configuration	No of electron	Z_{eff}	Ionic radii (pm)
P^{3-}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	18	15-10=+5	212
S^{2-}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	18	16-10=+6	184
Cl^{-}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	18	17-10=+7	181

Author Information

Aini Hidayah Mohamed is a lecturer from Faculty of Industrial Sciences & Technology Industry, Universiti Malaysia Pahang, Malaysia. She is also a chemist who is expert in general chemistry, industrial chemistry and natural product.