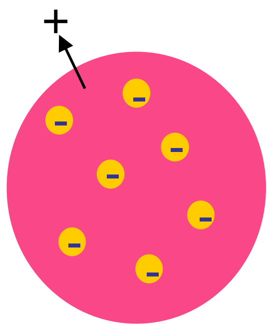
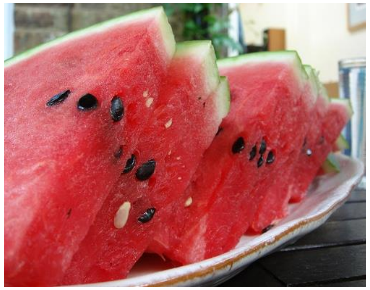
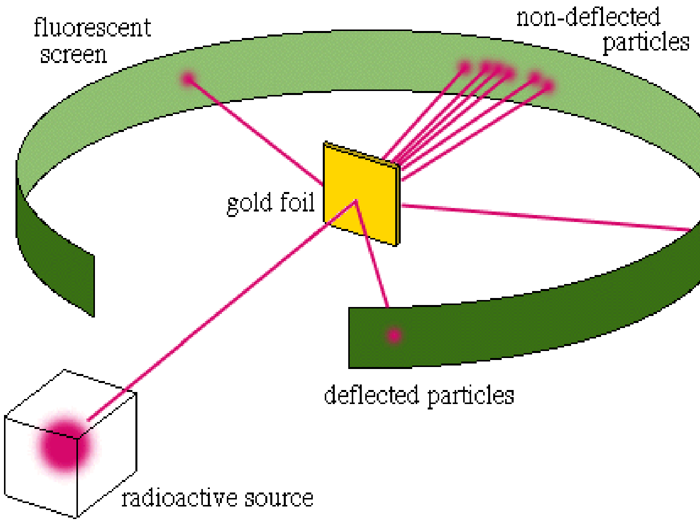
Electrons in Atoms
and
the Periodic Table

Structure of atom

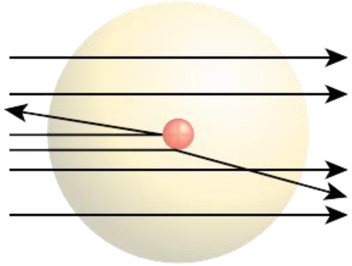


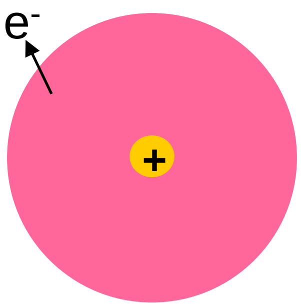




(Source of α particles)

Rutherford's model





Electromagnetic radiation

Energy is transferred by light.

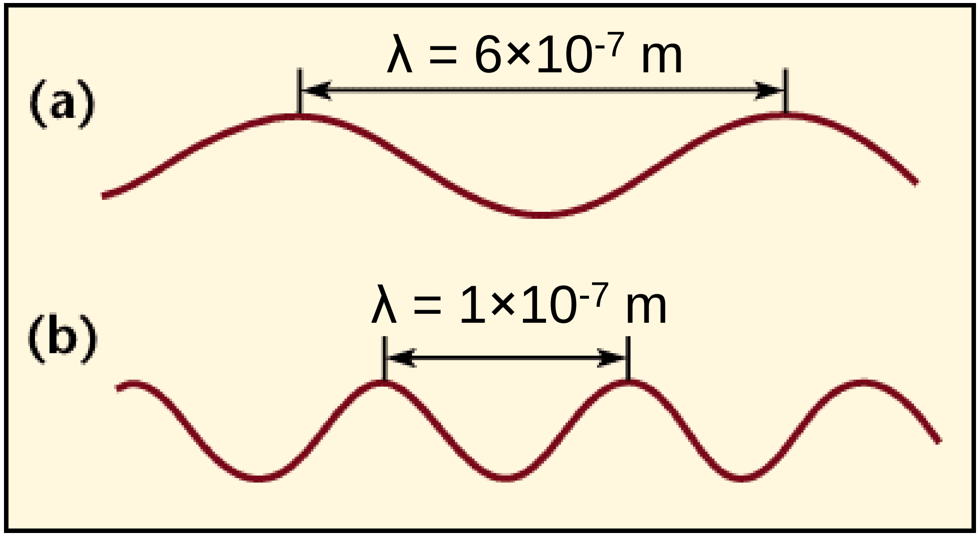
Electromagnetic radiation

A wave characterized by three properties:

Wave:
- Wavelength
- Frequency
- Speed

Electromagnetic radiation

Wavelength (λ): distance from one wave peak to the next.



Frequency (ν): number of peaks that pass a given point in one second.

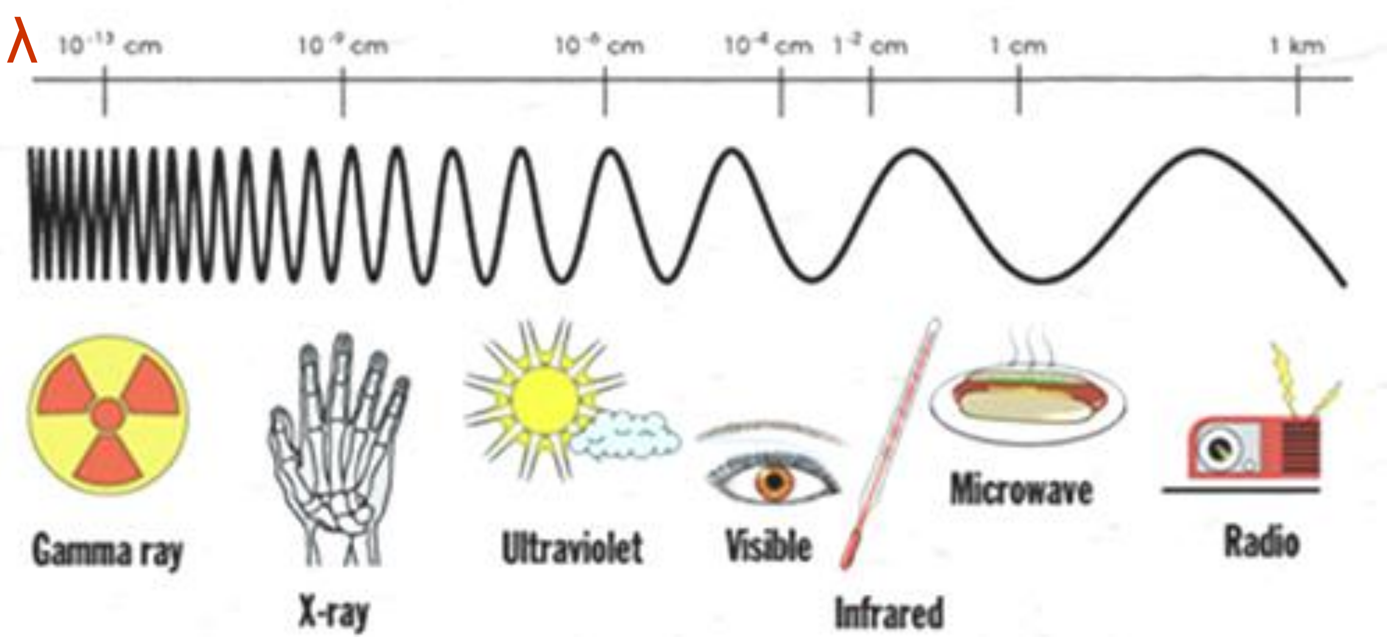
$$\lambda = \frac{c}{\nu}$$

c: speed of light = 3.0×10^8 m/s

Electromagnetic radiation

longer λ → lower ν

shorter λ → higher ν

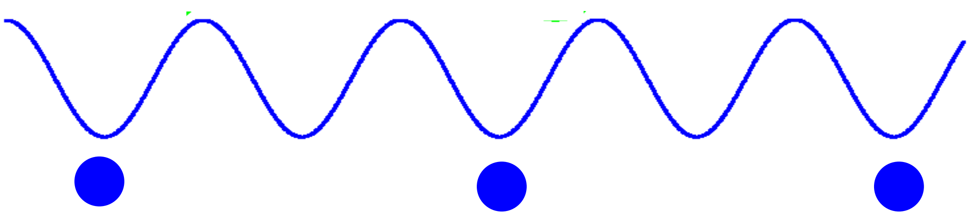


Electromagnetic spectrum

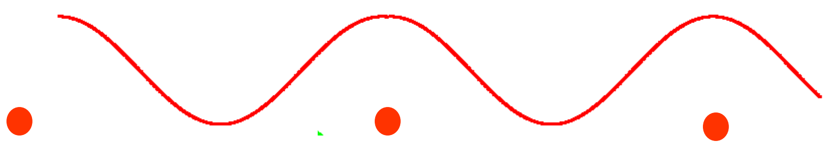
Electromagnetic radiation

Photon: a stream of tiny packets of energy.

(smallest unit of electromagnetic radiation)



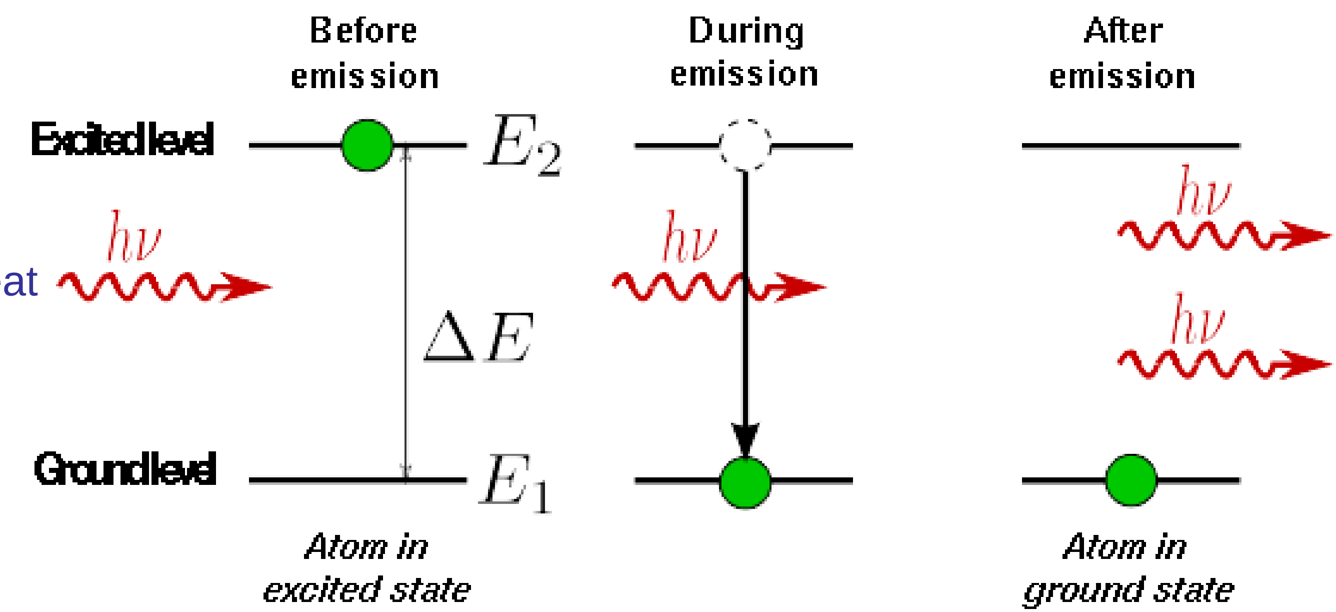
shorter λ (higher ν) → higher energy



longer λ (lower ν) → lower energy

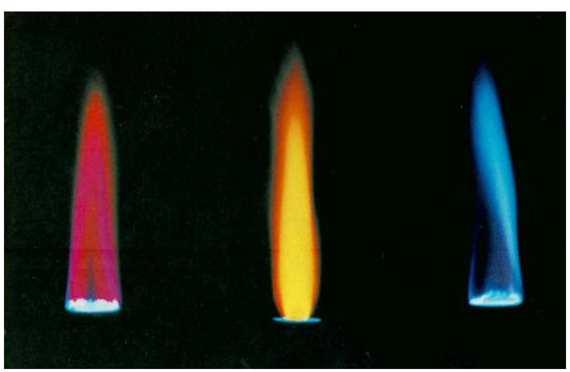
Emission of energy by atoms

Energy of heat (or …)

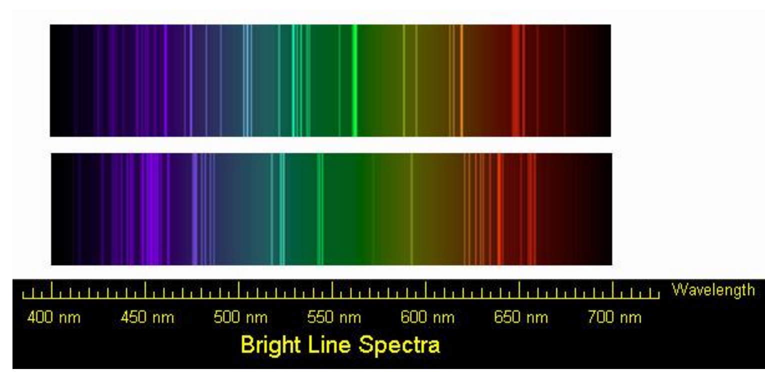


Emitted photons (light)

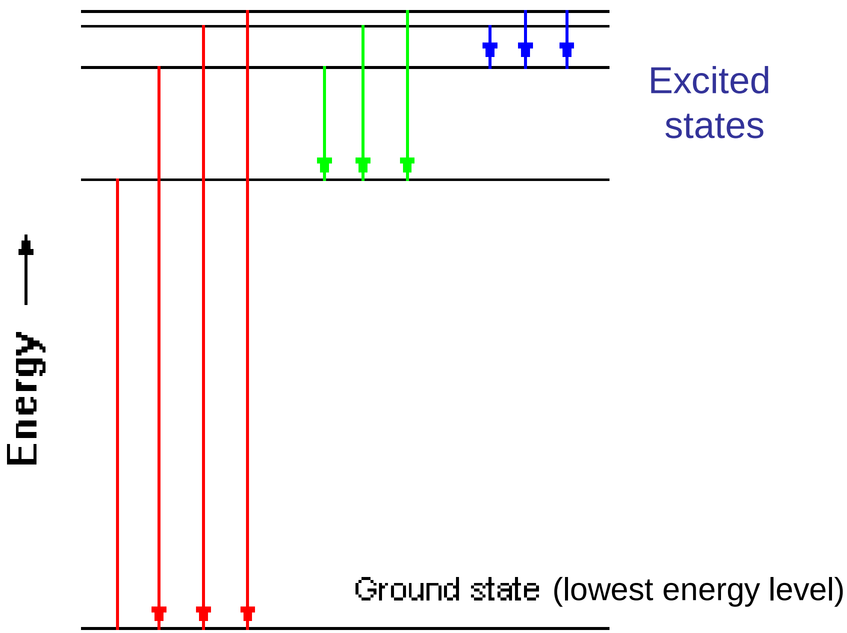
$$E_2 - E_1 = \Delta E = h\nu$$



Flame test



Emission of energy by atoms

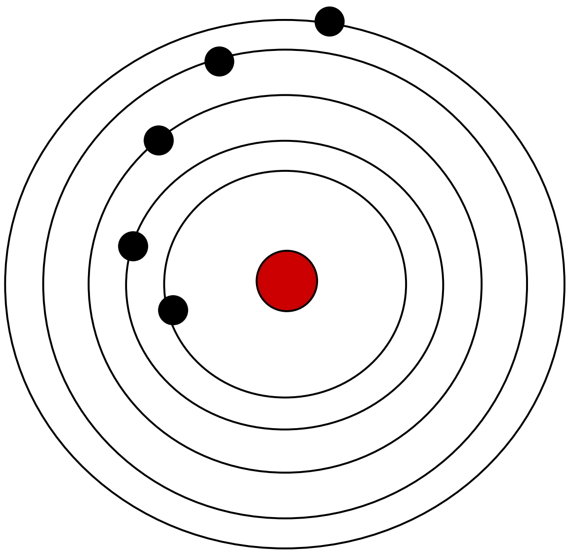


Only certain energy changes are allowed.

Energy levels are quantized.

Only certain types of photons are produced.

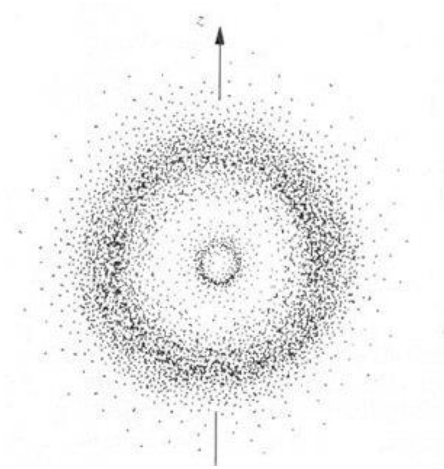
Bohr model

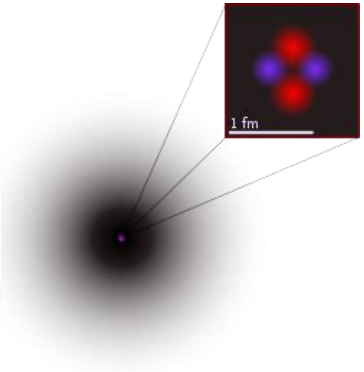


Electron orbits the nucleus in circles.

Electrons are moving in only allowed energy levels.

Wave mechanical model of atom

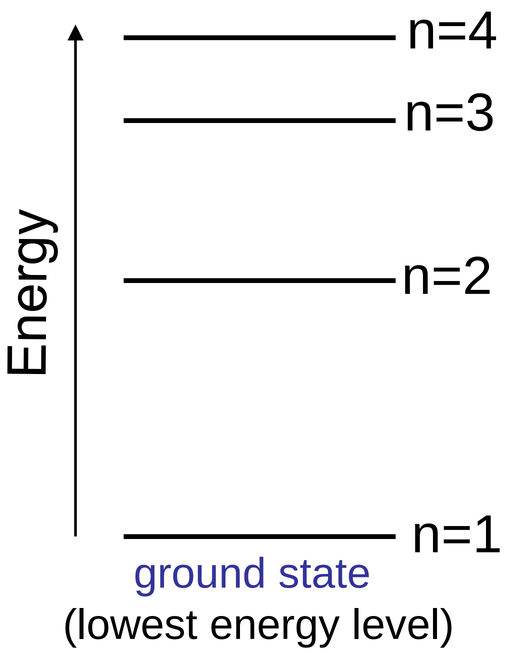




Electron acts as a wave.

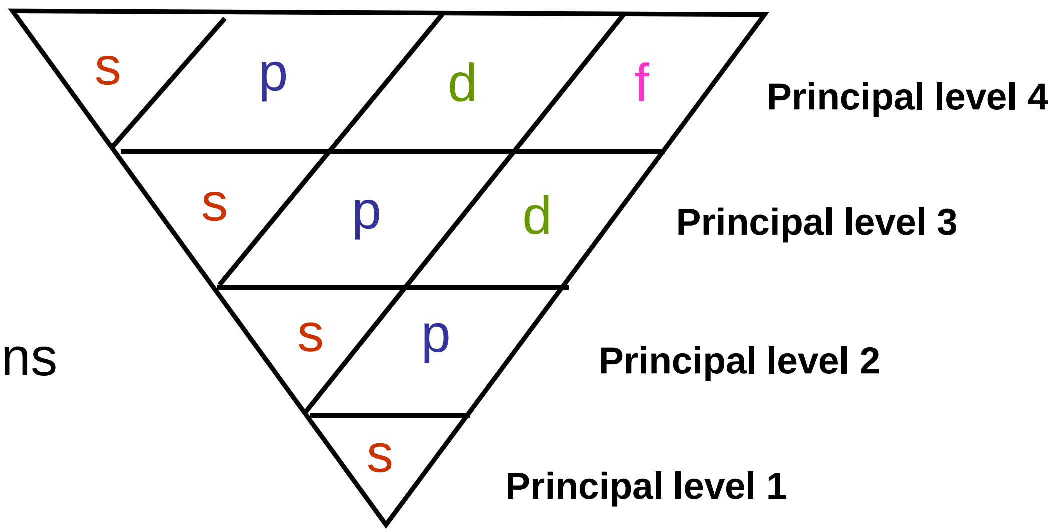
Electron does not orbit the nucleus in circles.

Electrons move randomly; however,
there is more chance to find them close to nucleus.

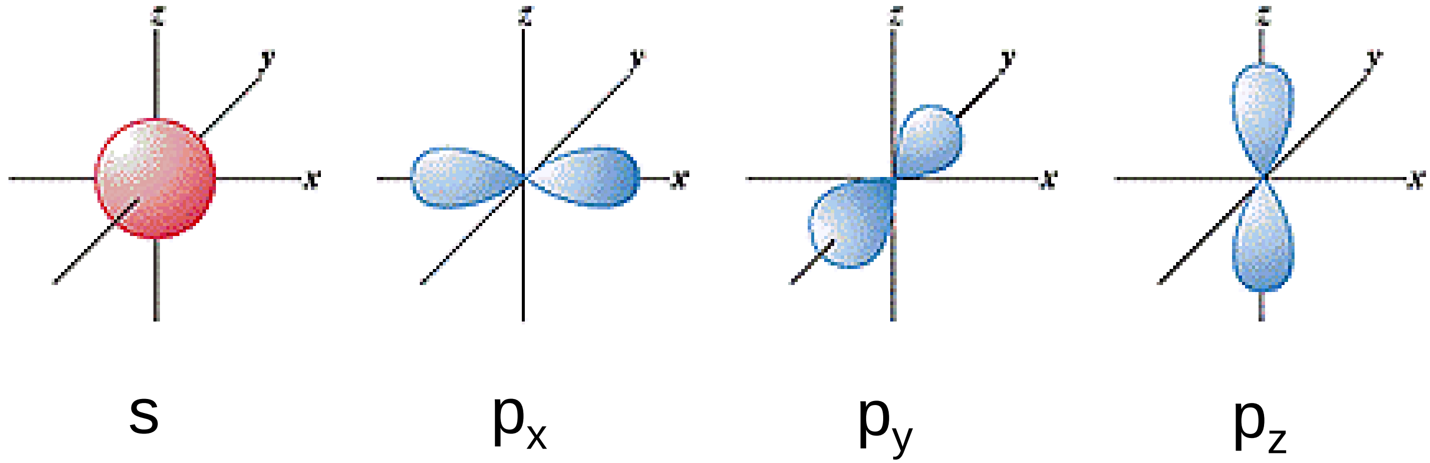


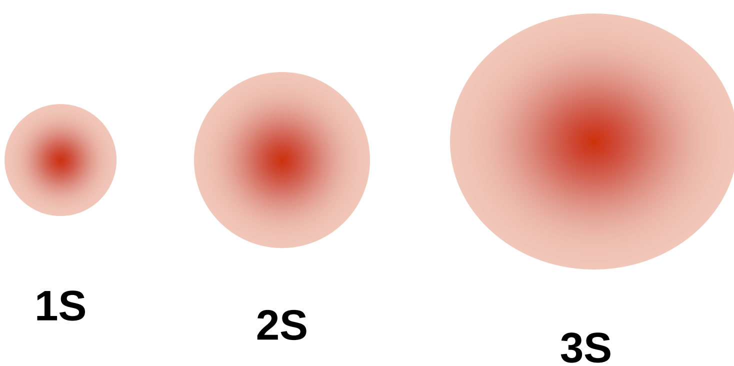
Principal energy levels

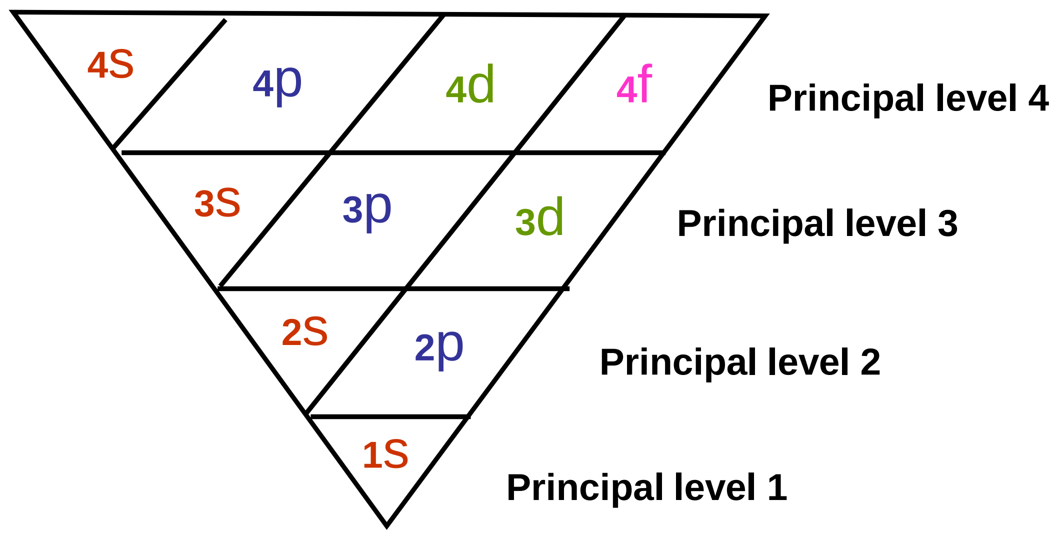
Sublevels: s p d f



Orbital: is a region of space and can hold maximum 2 electrons


z
y
x
s
p x
p y
p z

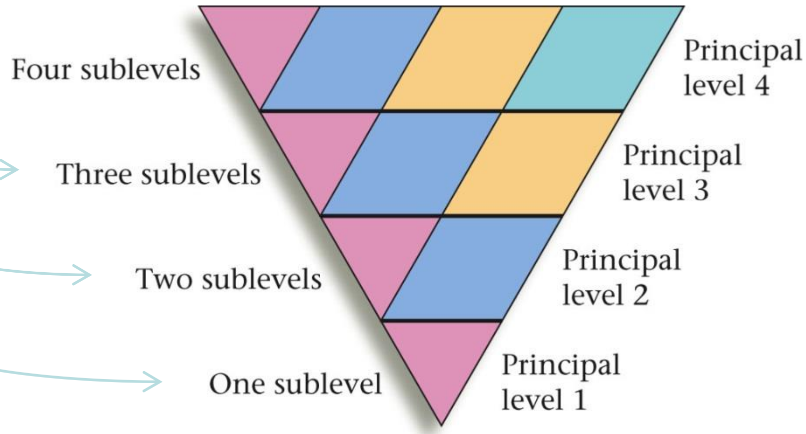

1S
2S
3S


4S
4p
4d
4f
Principal level 4
3S
3p
3d
Principal level 3
2S
2p
Principal level 2
1S
Principal level 1

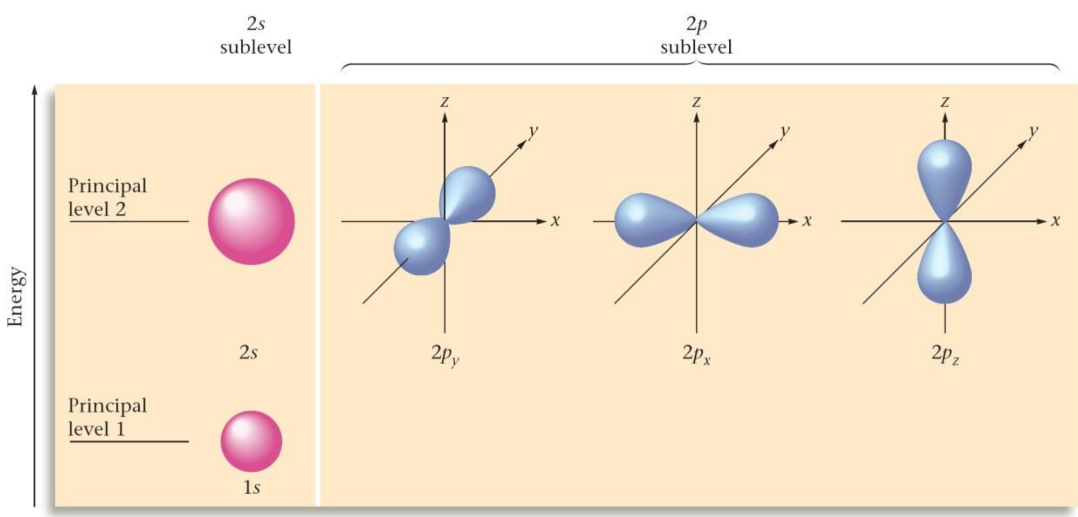
3 *s*, *p*, *d*

2 *s*, *p*

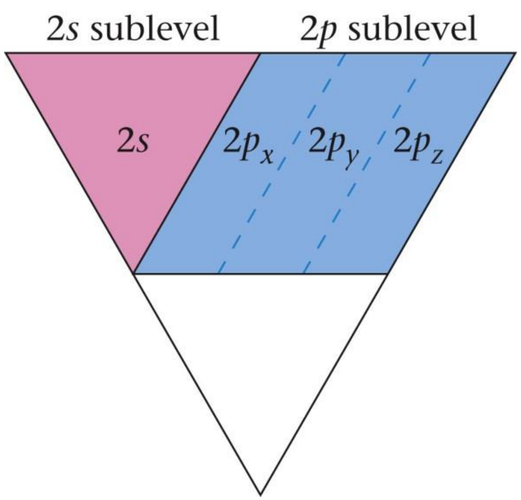
1 *s*



Four sublevels
Three sublevels
Two sublevels
One sublevel
Principal level 4
Principal level 3
Principal level 2
Principal level 1



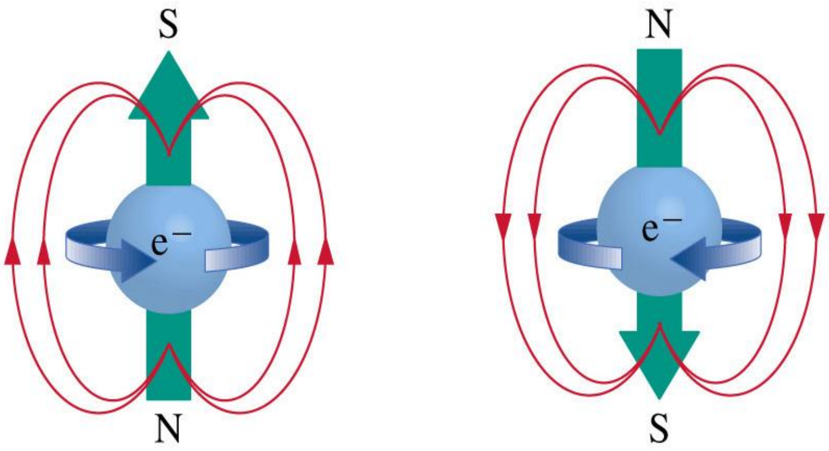
2s sublevel
2p sublevel
Energy
Principal level 2
Principal level 1
2s
1s
2p_y
2p_x
2p_z
z
y
x



2s sublevel
2p sublevel
2s
2p_x
2p_y
2p_z

Pauli exclusion principle

Orbital: is a region of space and can hold maximum 2 electrons



magnetic field

↓

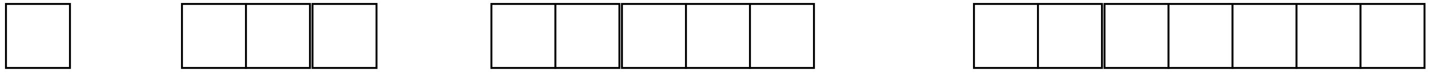
paired spins

Two electrons can stay together even with their opposite charges.

Sublevels: s p d f

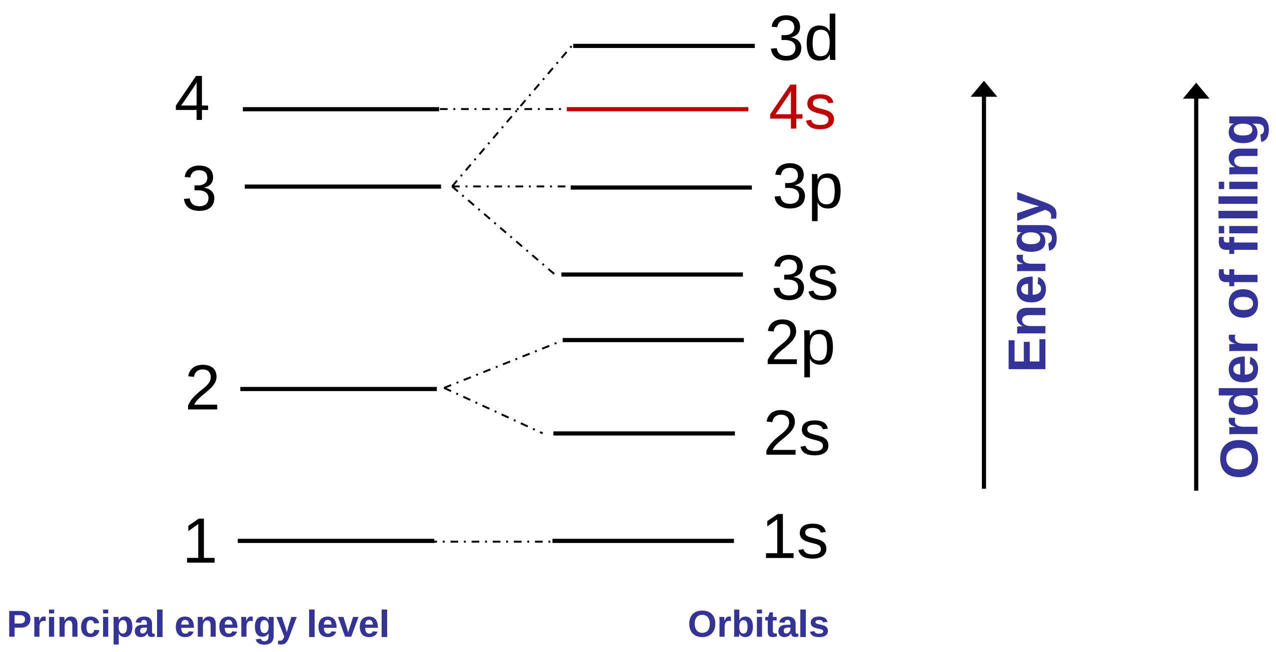
s p d f

P_x P_y P_z

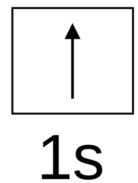
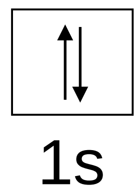
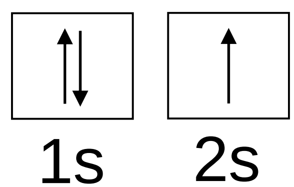
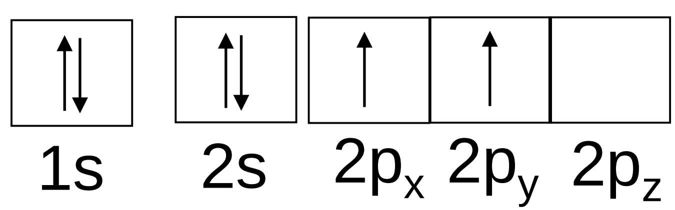


2 | 2+2+2=6 | 2+2+2+2+2=10 | 2+2+2+2+2+2+2=14

Level	Orbitals	Maximum number of electrons
1	1s	2
2	2s, 2p	2 + 6 = 8
3	3s, 3p, 3d	2 + 6 + 10 = 18
4	4s, 4p, 4d, 4f	2 + 6 + 10 +14 = 32

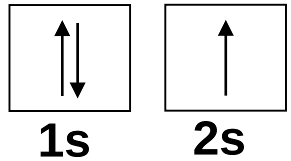


Electrons configuration: description of the orbitals that its electrons occupy.

	Orbital box diagrams	Electron configuration
H (1)		$1s^1$
He (2)		$1s^2$
Li (3)		$1s^2\ 2s^1$
C (6)		$1s^2\ 2s^2\ 2p^2$

Noble gas notation

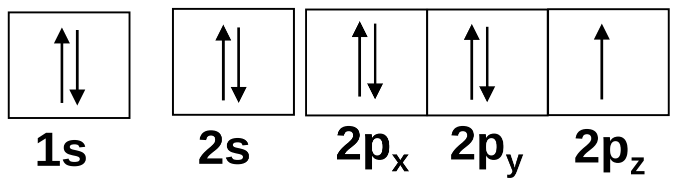
Li (3)



$1s^2\ 2s^1$

$[He]\ 2s^1$

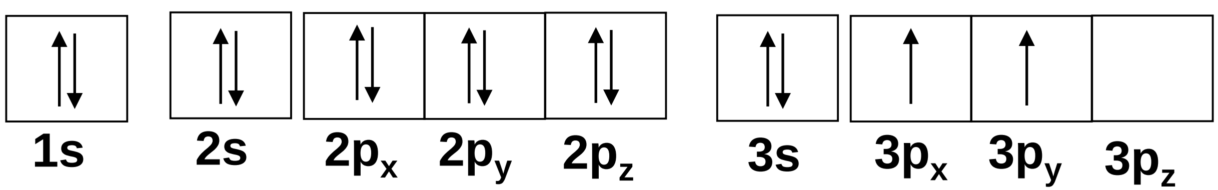
F (9)



$1s^2\ 2s^2\ 2p^5$

$[He]\ 2s^2\ 2p^5$

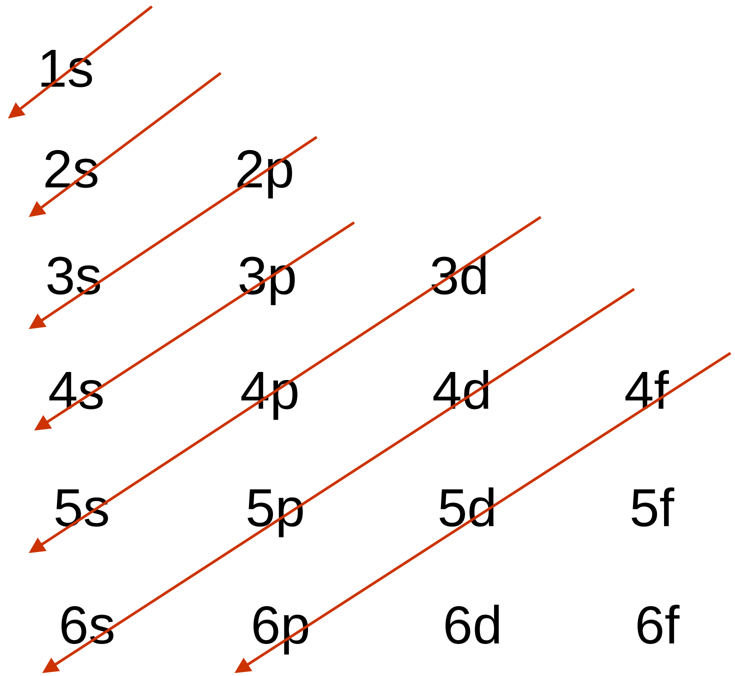
Si (14)

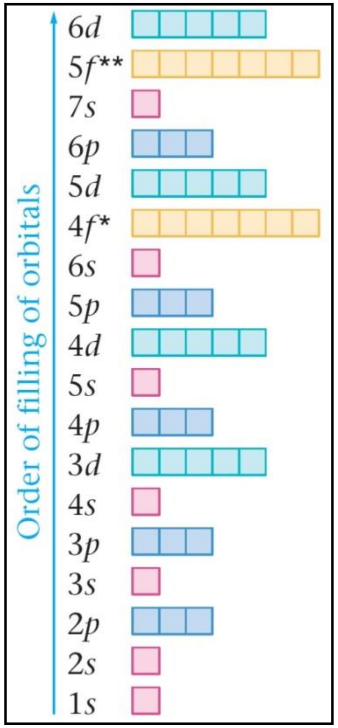


$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

$[Ne]\ 3s^2\ 3p^2$

Orbital filling order





1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s

Hf (72): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^2$

$[Xe]\ 6s^2\ 4f^{14}\ 5d^2$

Notice that Cr and Cu are exceptions to the usual trend.

Having half-filled d orbitals adds some stability.

K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
$4s^1$	$4s^2$	$3d^1$	$3d^2$	$3d^3$	$4s^1 3d^5$	$3d^5$	$3d^6$	$3d^7$	$3d^8$	$4s^1 3d^{10}$	$3d^{10}$	$4p^1$	$4p^2$	$4p^3$	$4p^4$	$4p^5$	$4p^6$

(You must be able to write the electron configurations for the first 4 periods.)

Valence level: outermost principle energy level

Valence electrons: electrons in highest principal energy level.

Cl (17)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$	→	7 valence electrons
Ar (18)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	→	8 valence electrons
C (6)	$1s^2\ 2s^2\ 2p^2$	→	4 valence electrons
Ne (10)	$1s^2\ 2s^2\ 2p^6$	→	8 valence electrons

Noble gases → Filled valence level

Only valance electrons are involved in chemical bond and chemical reactions.

Inner electrons (core electrons) are not involved.

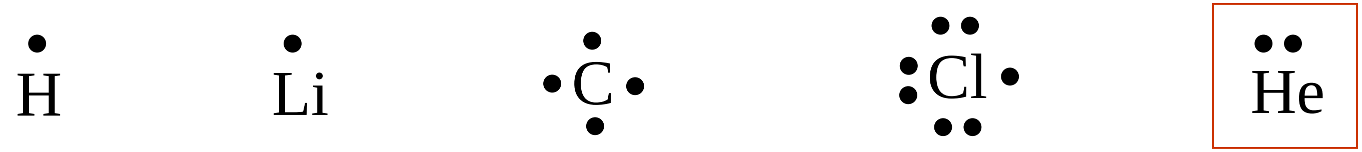
Core electrons ← $1s^2\ 2s^2\ 2p^6$ $3s^2\ 3p^6$ → Valance electrons

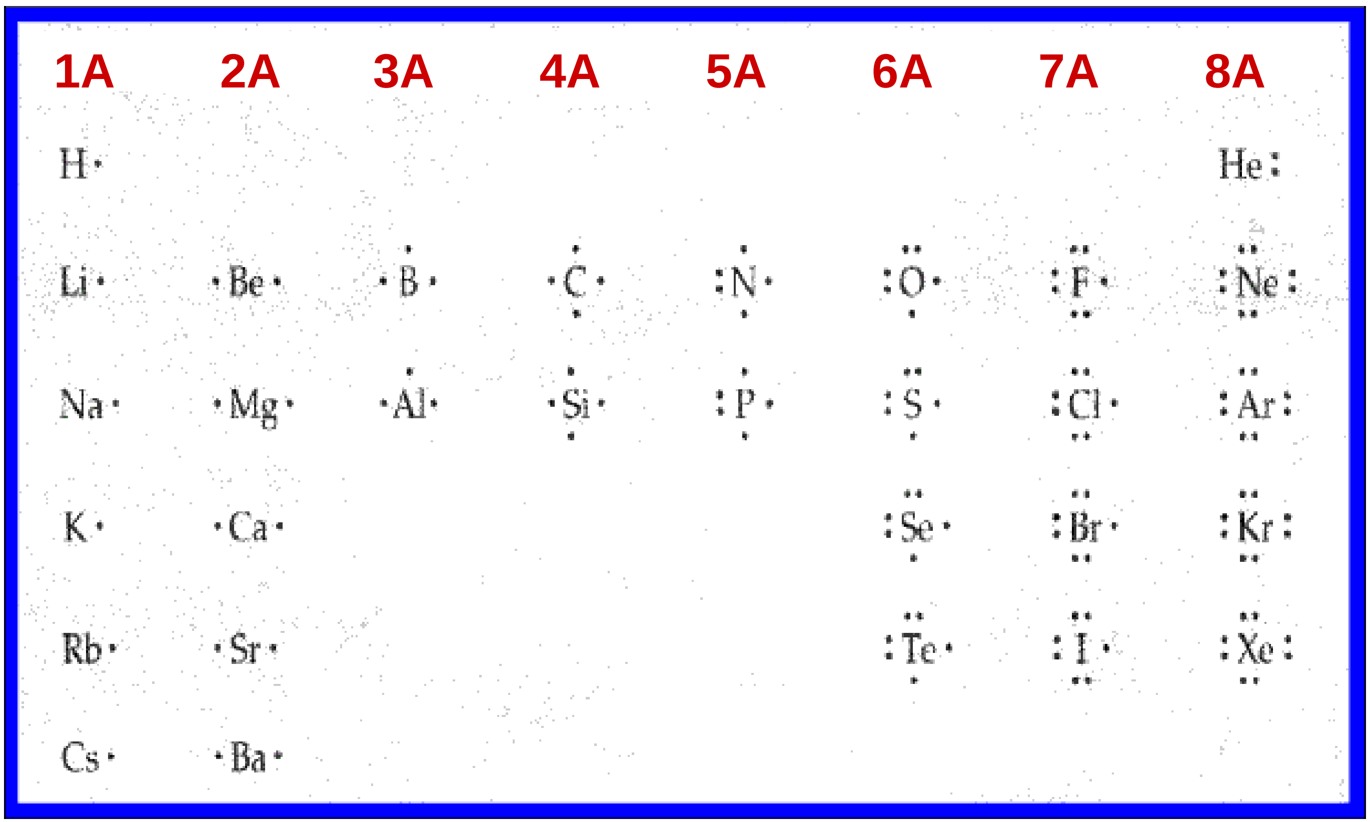
Elements in same column (group) have the same number of electrons in their valance levels.

↓

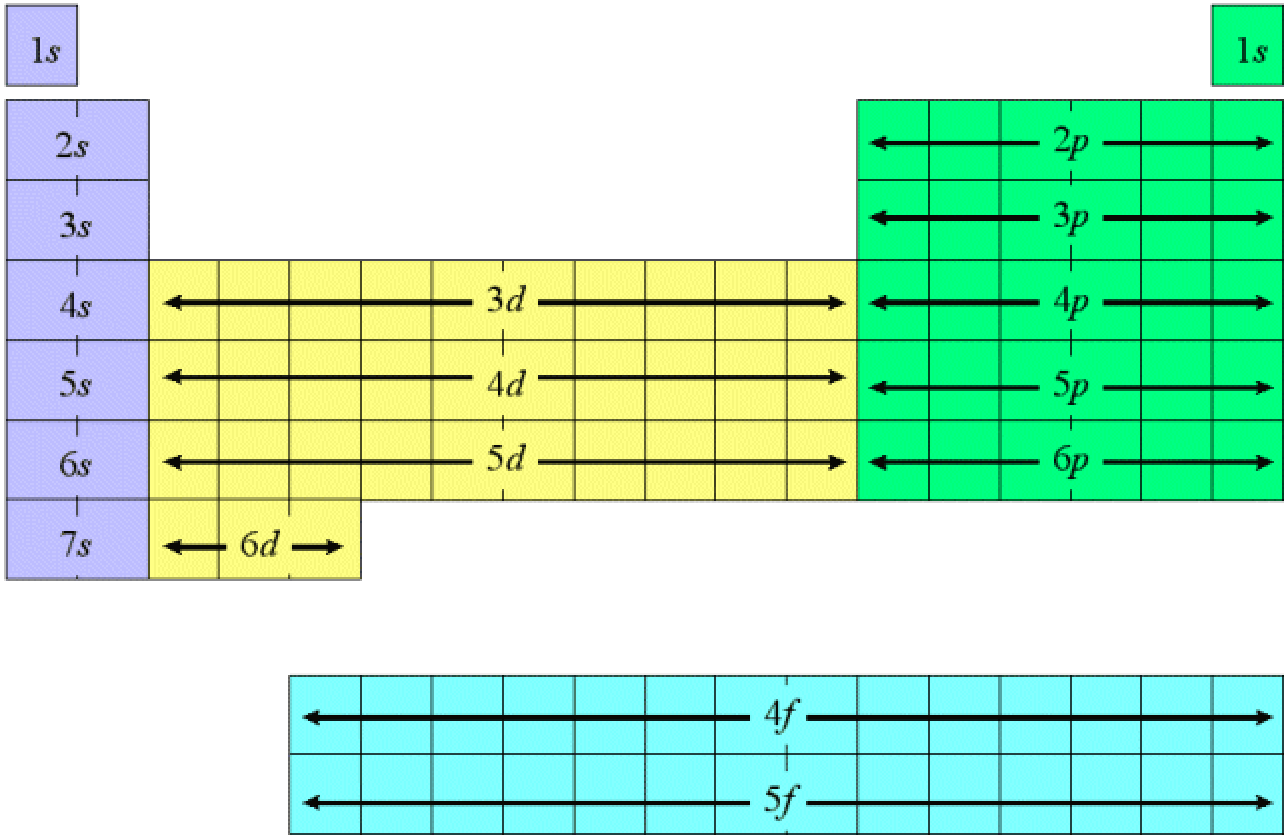
Same chemical and physical properties.

Lewis dot structure





Only for main-group element: # of group = # of valance electrons



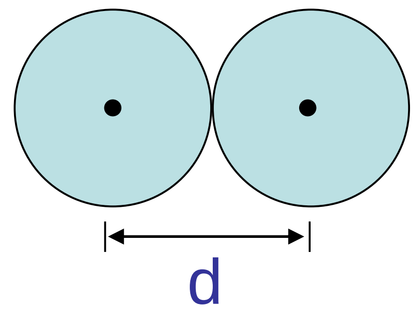
Main groups elements → s, p

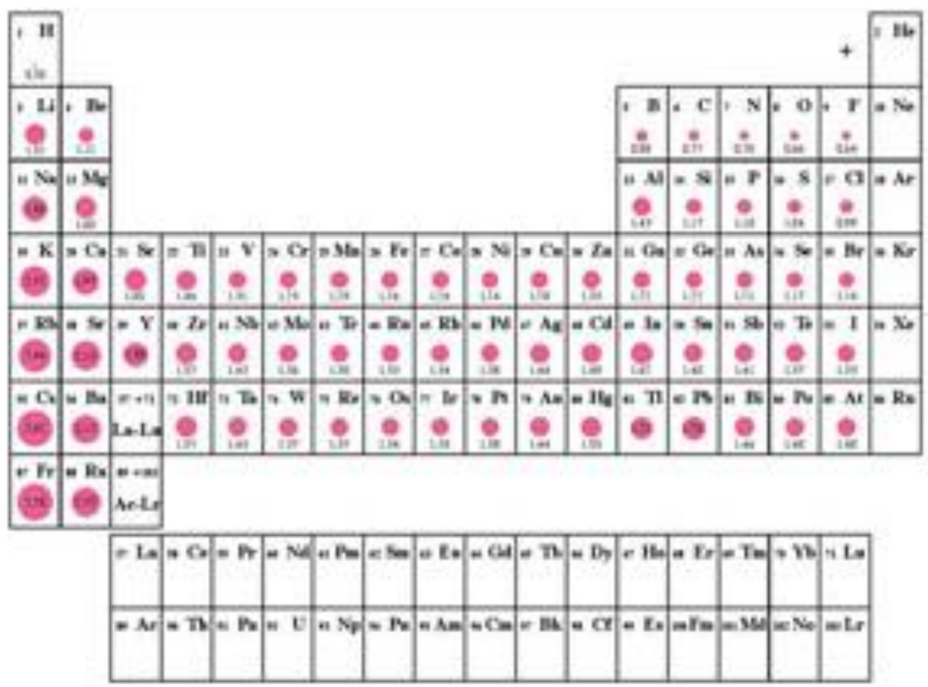
Transition elements → s, p, d

Inner transition elements → s, p, d, f

Atomic Size

Size of atom: is the size of its outermost occupied orbital.



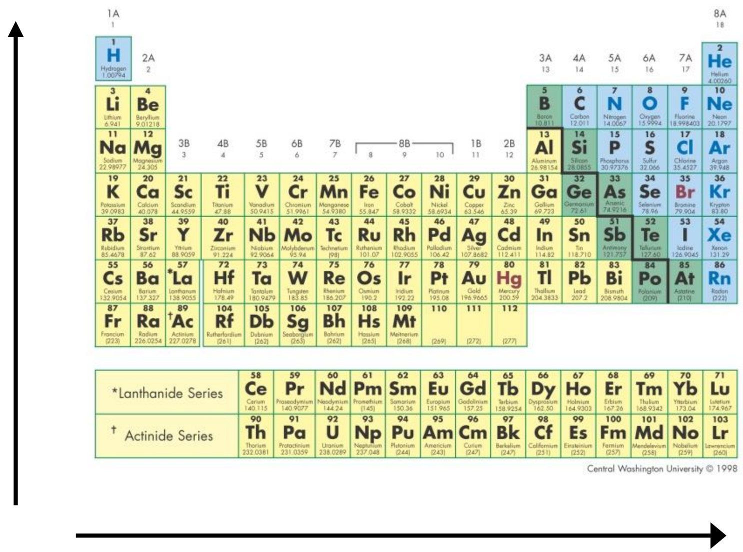


Ionization Energy

Li + energy → Li^{+} + e^{-}

ion

Ionization energy: the energy required to remove the most loosely held electron from an atom in the gaseous state.



Ionization energy

Ionization energy

Ions Electron Configuration

- Ions have *electron configurations* where the neutral atom has lost or gained electrons.

Oxygen, O, $\mathbf{1s^2 2s^2 2p^4}$

Oxide, O^{2-}, $\mathbf{1s^2 2s^2 2p^6}$

Sodium, Na, $\mathbf{1s^2 2s^2 2p^6 3s^1}$

sodium cation, Na^+, $\mathbf{1s^2 2s^2 2p^6 3s^0 = 1s^2 2s^2 2p^6}$

- Notice both O^{2-} and Na^+ have electron configurations identical to the noble gas neon.

Practice

- What is the correct electron configuration for the element **phosphorus**?
- What is the correct electron configuration for the element **titanium**?
- Which noble gas electron configuration is exactly the same as the electron configuration for the **Ca^{2+} ion**?
- Which noble gas electron configuration is exactly the same as the electron configuration for the **Se^{2-} ion**?