Electron Configuration
Organization of electrons in atoms

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(Chemistry Notes)

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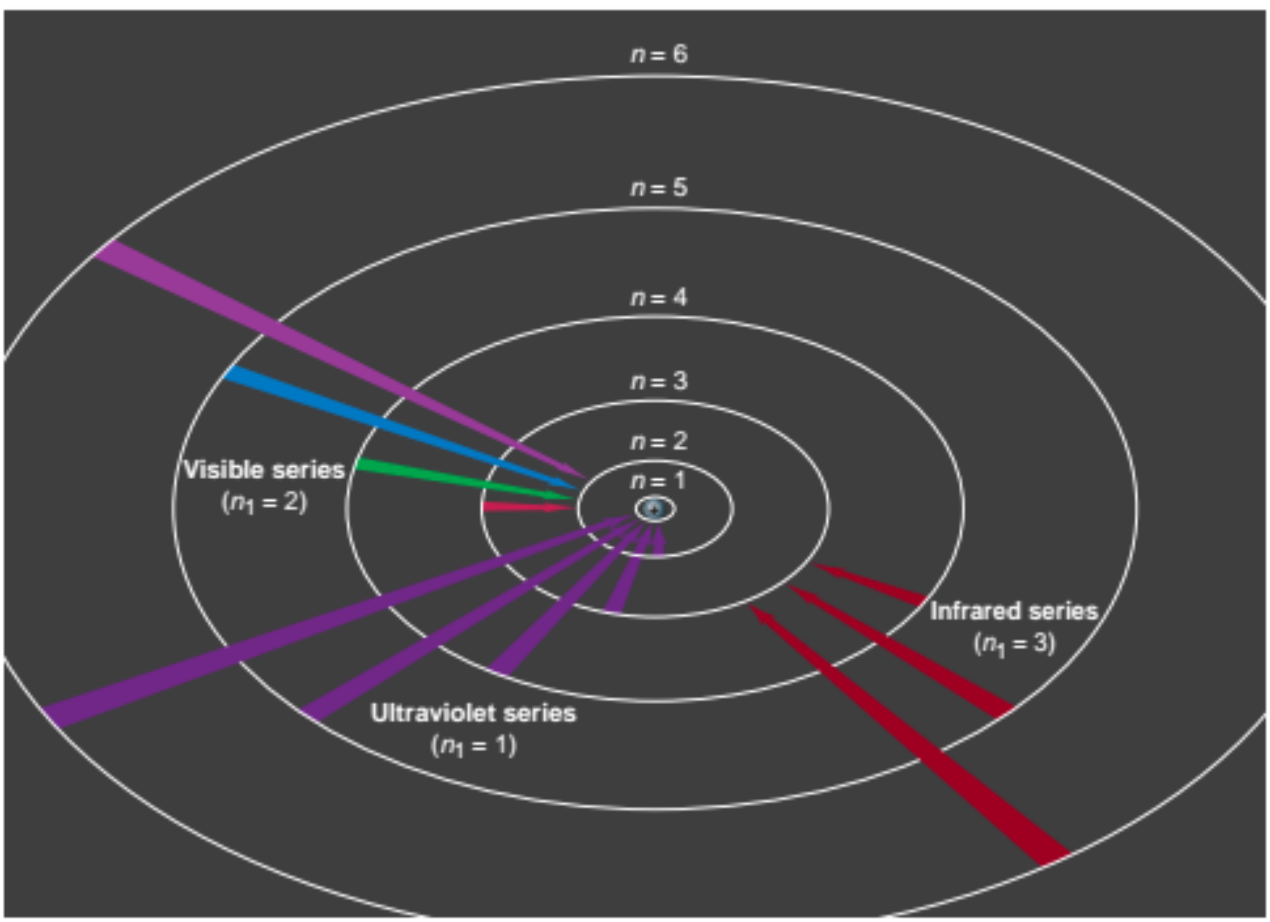
Simplest Structure of an Atom.

The principal quantum number (n)

Nucleus is in the center and positively charged (+).

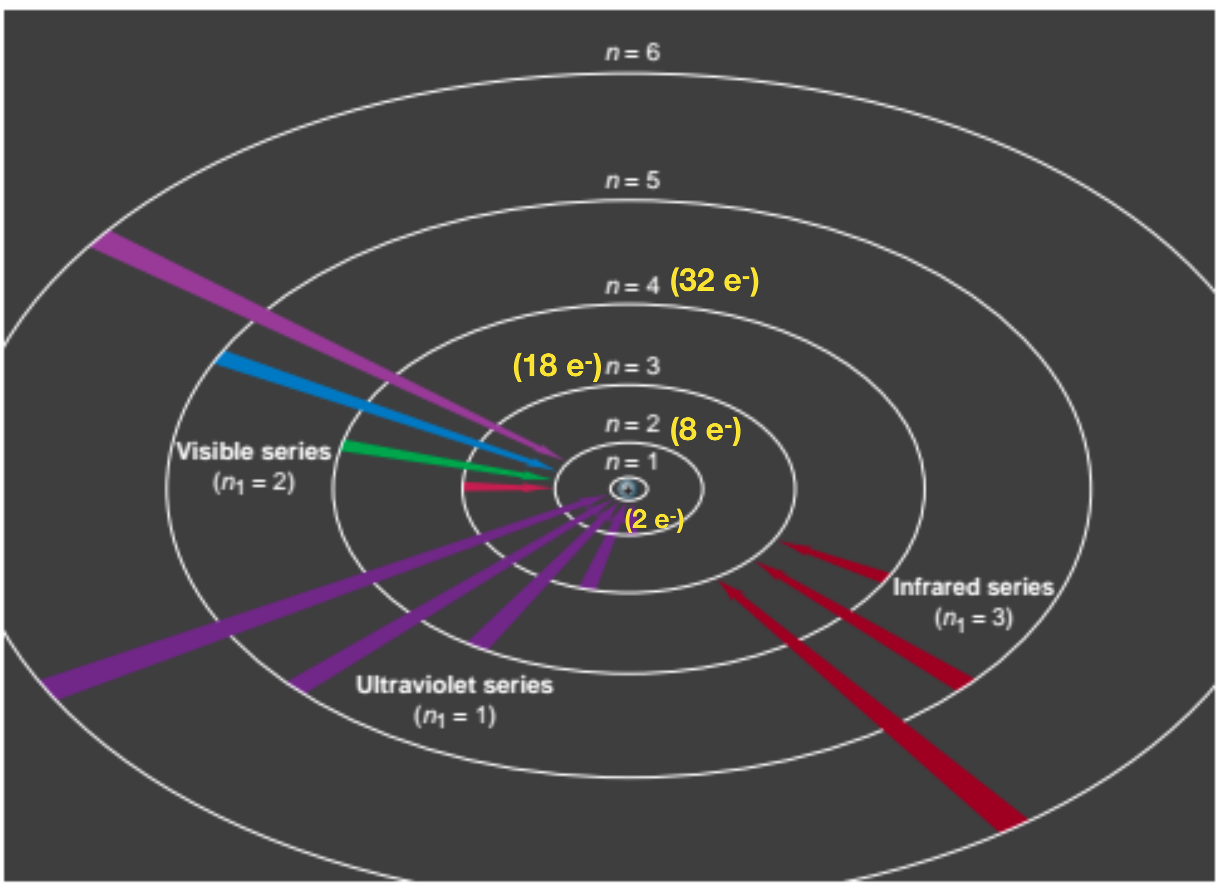
Electrons (e^-) are spinning around on energy levels (n = 1, 2, 3, 4, 5, 6..). Energy level (n = 1) is the closest to the nucleus. Energy levels are sometimes called Shells. Below is a basic model of how an atom looks like. n is called the principal quantum number.



Maximum Number of Electrons on Each Energy Level.

The maximum number of electrons that each energy level (n) can hold is given by the formula: $2\,n^2$

Maximum Number of Electrons on Each Energy Level $2(n)^2$		
n = **1**	$2(1)^2$	2 electrons (2 e^-)
n = **2**	$2(2)^2$ = 2x4	8 electrons (8 e^-)
n = **3**	$2(3)^2$ = 2x9	18 electrons (18 e^-)
n = **4**	$2(4)^2$ = 2x16	32 electrons (32 e^-)



Energy Levels have Orbitals (Sub-levels).

Energy levels (shells) are divided into sub-levels (sub-shells or orbitals). There are 4 types of orbitals: s, p, d, f.

s can hold a maximum of 2 electrons (s^2)

p can hold a minimum of 6 electrons (p^6)

d can hold a maximum of 10 electrons (d^{10})

f can hold a maximum of 14 electrons. (f^{14})

(Azimuthal) momentum quantum number l,

These sublevels (orbitals) are represented by the angular (Azimuthal) momentum quantum number l, and defines the shape of the orbital.

s has $l = 0$
p has $l = 1$
d has $l = 2$
f has $l = 3$

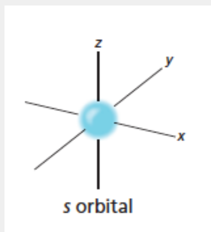
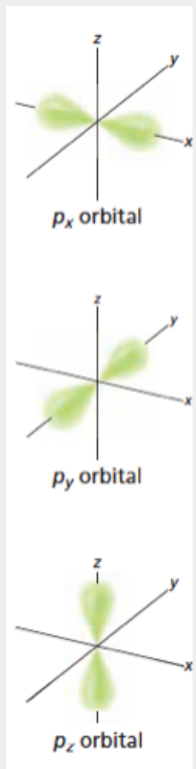
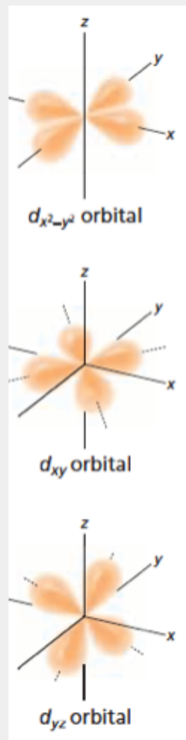
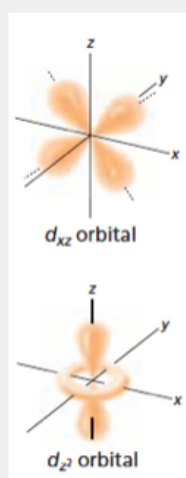
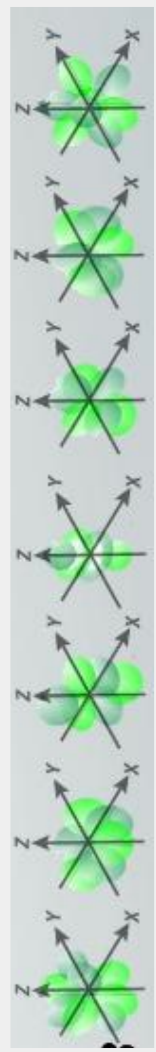
Magnetic quantum number, m_l

This quantum number depends on l. The magnetic quantum number gives the three-dimensional orientation of each orbital. The magnetic quantum number has integer values between $-l$ and $+l$.

$$m_l = (-l \text{ to } 0 \text{ to } +l)$$

s has $l = 0$, so, $ml = 0$ (one orientation/orbital)
p has $l = 1$, so, $ml = -1, 0, +1$ (3 orientations/orbitals)
d has $l = 2$, so, $ml = -2, -1, 0, +1, +2$ (5 orientations/orbitals)
f has $l = 3$, so, $ml = -3, -2, -1, 0, +1, +2, +3$ (7 orientations/orbitals)

Each orientation/orbital can hold 2 electrons.
S (2 x 1 = 2 e^-), P (2 x 3 = 6 e^-), d (2 x 5 = 10 e^-), f (2 x 7 = 14 e^-).

Orbital	**s**	**p**	**d**	**f**
Maximum electrons it holds	**2 e⁻**	**6 e⁻**	**10 e⁻**	**14 e⁻**
l	0	1	2	3
m*l* ***– l to 0 to +l***	m*l* = 0 (1 orientation / orbital)	m*l* = -1, 0, +1 (3 orientations /orbitals)	m*l* = -2, -1, 0, +1, +2 (5 orientations / orbitals)	m*l* = -3, -2, -1, 0, +1, +2, +3 (7 orientations / orbitals)
Orientation S: spherical P: 2 lobes of 3 orientations along x, y and z axis d: 4 lobes and 5 orientations Each orientation can hold a maximum of 2 electrons.	 *s* orbital	 p_x orbital p_y orbital p_z orbital	 $d_{x^2-y^2}$ orbital d_{xy} orbital d_{yz} orbital  d_{xz} orbital d_{z^2} orbital	

Orbitals on Each Energy Level (n).

For each energy level (n), the number of orbitals is governed by the (Azimuthal) momentum quantum number l. The values of l begins at 0 and increases to (n – 1).

l goes from 0 to (n – 1).

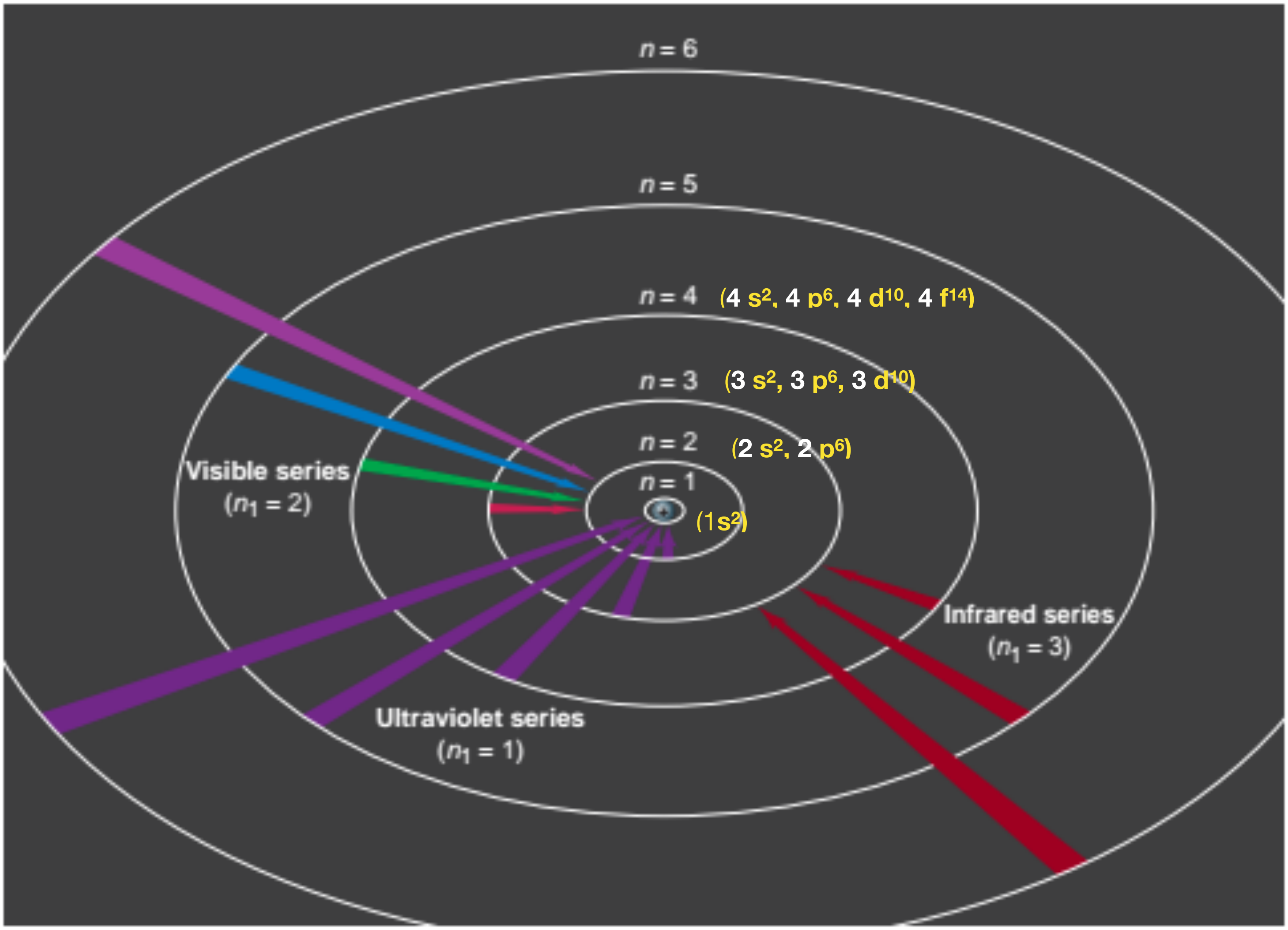
Example:

Energy level **1** (n = **1**): l begins at 0 and increase to (n – 1) = (1-1) = 0. So l = 0. So **S** orbital which can hold a maximum of **2** electron. The orbital is represented by **$1s^2$**

Recall: s has l = 0, p has l = 1, d has l = 2, f has l = 3

a	s	p	d	f	
Maximum electrons it holds	**$2\ e^-$**	**$6\ e^-$**	**$10\ e^-$**	**$14\ e^-$**	
Angular quantum number l	0	1	2	3	
Energy level n = **1** n-1 = 1-1 = 0 l goes from 0 to 0	√				Maximum Total: $2\ e^-$ $1\mathbf{s}^2$
Energy level n = **2** n-1 = 2-1 = 1 l goes from 0 to 1	√	√			Maximum Total: $8\ e^-$ $2\ \mathbf{s}^2$, $2\ \mathbf{p}^6$
Energy level n = **3** n-1 = 3-1 = 2 l goes from 0, to 2	√	√	√		Maximum Total: $18\ e^-$ $3\ \mathbf{s}^2$, $3\ \mathbf{p}^6$, $3\ \mathbf{d}^{10}$
Energy level n = **4** n-1 = 4-1 = 3 l goes from 0 to 3	√	√	√	√	Maximum Total: $32\ e^-$ $4\ \mathbf{s}^2$, $4\ \mathbf{p}^6$, $4\ \mathbf{d}^{10}$, $4\ \mathbf{f}^{14}$

Top picture is a symbolic representation of the energy level and orbitals. Bottom picture shows the orbitals in 3D and their orientations in space. Notice the 3 orientations of the p orbital (two lobes along the x, y and x axis together. The s orbital is spherical.



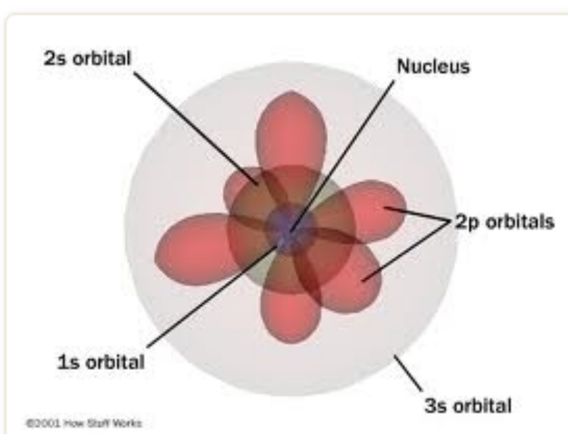


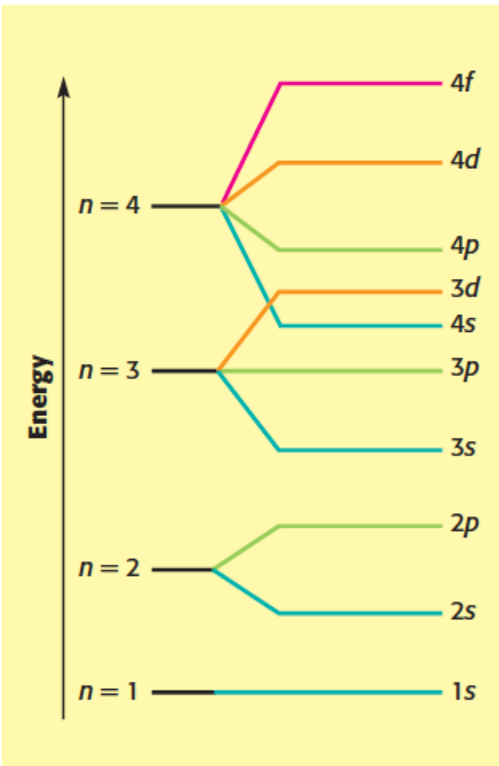
Table 6.2 below is a summary table.

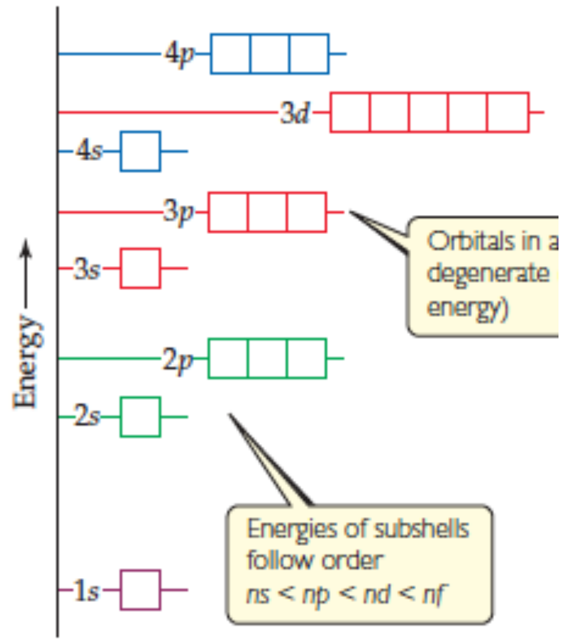
TABLE 6.2 • Relationship among Values of n, l, and m_l through $n = 4$

n	Possible Values of l	Subshell Designation	Possible Values of m_l	Number of Orbitals in Subshell	Total Number of Orbitals in Shell
1	0	1*s*	0	1	1
2	0	2*s*	0	1	
	1	2*p*	1, 0, −1	3	4
3	0	3*s*	0	1	
	1	3*p*	1, 0, −1	3	
	2	3*d*	2, 1, 0, −1,−2	5	9
4	0	4*s*	0	1	
	1	4*p*	1, 0, −1	3	
	2	4*d*	2, 1, 0, −1, −2	5	
	3	4*f*	3, 2, 1, 0, −1, −2, −3	7	16

Electron Shell Filling Order

The diagrams below are all the same representation of Electron Shell Filling Order. They illustrate how the energy of orbitals can overlap such that the 4 s fills before 3d.





Notice:

S is represented by one box. One orientation

P is represented by 2 boxes for the 3 orientations.

Px	Py	Pz

d is represented by 5 boxes for the 5 orientations

dxy	dxz	dy-z	dz2	dx2-y2

The electronic configuration starts from bottom to top with the order: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, and more.

Electron configurations:

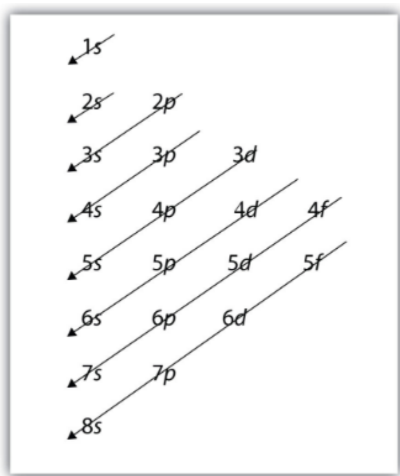
is a shorthand notations of the arrangement of electrons in an atom. The number of electrons is the atomic number (Z) in the periodic table. You start by filling the orbitals close to the nucleus with electrons. The order is as explained in the previous page:
1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, ……

Table 6.3 below shows how to write it.

TABLE 6.3 • Electron Configurations of Several Lighter Elements

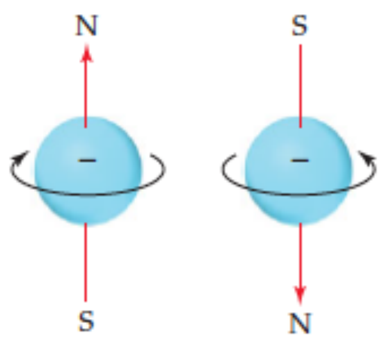
Element	Total Electrons	Orbital Diagram 1s	2s	2p	3s	Electron Configuration
Li	3	↑↓	↑			$1s^22s^1$
Be	4	↑↓	↑↓			$1s^22s^2$
B	5	↑↓	↑↓	↑		$1s^22s^22p^1$
C	6	↑↓	↑↓	↑ ↑		$1s^22s^22p^2$
N	7	↑↓	↑↓	↑ ↑ ↑		$1s^22s^22p^3$
Ne	10	↑↓	↑↓	↑↓ ↑↓ ↑↓		$1s^22s^22p^6$
Na	11	↑↓	↑↓	↑↓ ↑↓ ↑↓	↑	$1s^22s^22p^63s^1$

This side table can help organizing the electronic configurations up to energy level 8. The order is
1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p, 8s…..



Spin magnetic quantum number m_s = = +1/2 or -1/2

Electron spin. The electron behaves as if it were spinning about an axis, thereby generating a magnetic field whose direction depends on the direction of spin. The two directions for the magnetic field correspond to the two possible values for the spin quantum number, $m_{s,}$(+ 1/2, - 1/2).



An arrow pointing upwards has m_s = + 1/2
An arrow pointing downward has m_s =-1/2

Pauli's exclusion principle: No two electrons can fill one orbital with the same spin. Therefore, two electrons in the same orbit must have opposite spins.

For degenerated orbitals, electrons fill each orbital singly before any orbital gets a second electron.