CHEMISTRY

(FOR IIT, NEET, AIIMS)

Class – XI

Chapter : Atomic Structure

Topic : *Quantum Numbers*

Quantum Numbers

- "The numbers which represent the position and energy of electrons in an atom are called Quantum numbers."
- According to modern concept, following four quantum numbers are required to represent the position and energy of an electron in an atom completely-

(1) Principal quantum number (n)

(2) Azimuthal quantum number (l)

(3) Magnetic quantum number (m)

(4) Spin quantum number (s)

➢ Principal quantum number (n)

- This quantum number represents Principal energy level or shell of electron. It is denoted by “n” and it can have any integral value except zero. Thus,

  Permitted values of n = 1, 2, 3, 4,-----(any integral value except zero)

- Depending upon the value of n being 1, 2, 3, 4,------ etc. the shells are designated as K, L, M, N,----- shells respectively.

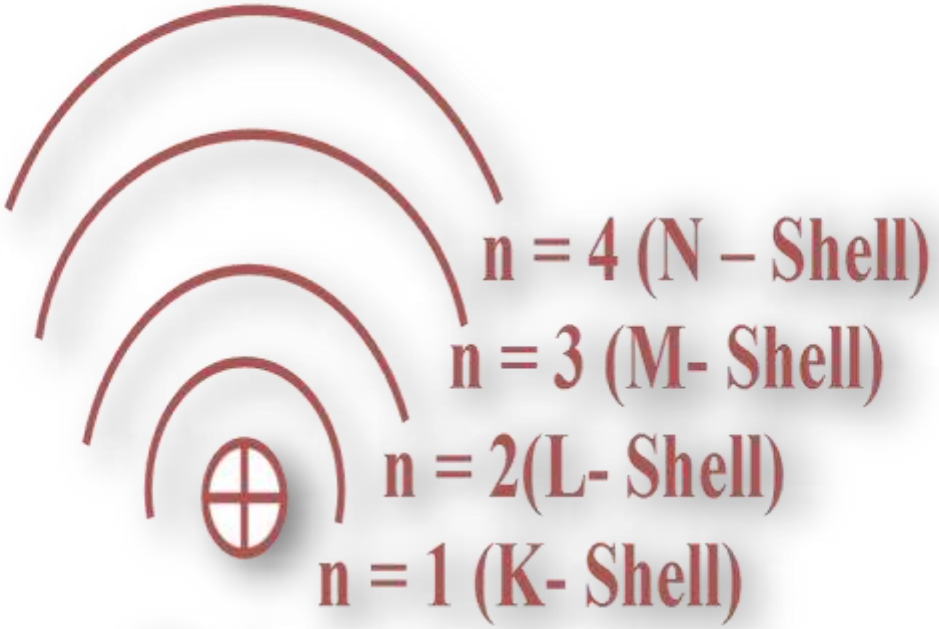


Fig- Different shells of an atom

➢Principal quantum number, n also represents the energy of electrons in an atom. For example, for hydrogen atom and hydrogen like ions containing only one electron, the energy of electron in n^{th} shell is given by following formula-

$$E_n = \frac{-2\pi^2 m e^4 Z^2}{n^2 h^2}$$

Where, m = mass of electron

e = charge of electron

Z = atomic number

n = Principal quantum number

h = Planck's constant (6.62×10^{-34}Js)

- It is clear that, the energy of electron increases with increase of the value of principal quantum number, n.
- Principal quantum number, n also represents the average distance of electron from nucleus. For example, for hydrogen atom and hydrogen like ions containing only one electron, the radius of n^{th} shell is given by following formula-

$$r_n = \frac{n^2 h^2}{4\pi^2 m e^2 Z}$$

- Thus, the average distance of electron from nucleus increases with increase of the value of principal quantum number, n.

(2) Azimuthal quantum number (l)

➢This quantum number represents sub- energy level or sub-shell of electron. It is denoted by "l" and its value depends upon the value of principal quantum number, n. It can have any integral value from 0 to (n-1). Thus,

Permitted values of l = 0 to (n-1) (any integer except zero)

Here, if n = 1 (K-shell), then l = 0

if n = 2 (L-shell), then l = 0, 1

if n = 3 (M-shell), then l = 0, 1, 2

if n = 4 (N-shell), then l = 0, 1, 2, 3

➢It is clear that, the total values of l is equal to the value of n.

➢Depending upon the value of l being 0, 1, 2, 3,------ etc., the sub-shells are designated as s, p, d, f,----- sub-shells respectively.

Value of 'l'	0	1	2	3
Designation of sub-shell	s	p	d	f

➢Each value of azimuthal quantum number, l represents a definite sub-shell. Hence, total number of sub-shells in a definite shell, corresponds to the total values of l for respective shell. For example,

➢For K-shell (n = 1), there is only one value of l i.e. 0. Hence, K-shell contains only one sub-shell called s-sub-shell.

➢For L-shell (n = 2), there are two values of l i.e. 0 and 1. Hence, L-shell contains two sub-shells called s and p-sub-shells respectively.

➢Similarly, M-shell contains three sub-shells (s, p and d) and N - shell contains four sub-shells (s, p, d and f sub-shells).

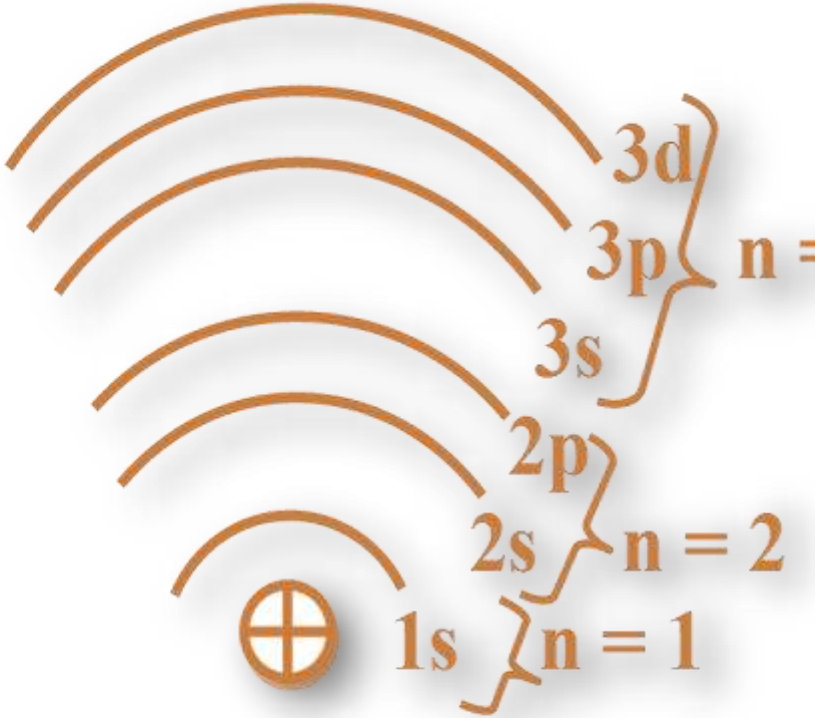


Fig.-Subshells of different Shells

- If for an electron
  n = 2
  l = 0
- If for an electron
  n = 3
  l = 1

➢Azimuthal quantum number, l also represents angular momentum (mvr) of an electron as per the following relation-

$$mvr = \frac{h}{2\pi}\sqrt{l(l+1)}$$

$$= \hbar\sqrt{l(l+1)}$$

➢Hence, this quantum number is also called angular momentum quantum number.

(3) Magnetic quantum number (m)

- This quantum number represents the orbital of the electron.
- It is denoted by "m" and its value depends upon the value of azimuthal quantum number, l. It can have any integral value from -l through zero to +1. Thus,

Permitted values of m = - l ------- 0 -------- + l

Here, if 1 = 0 (s sub-shell) then, m = 0

if l = 1 (p sub-shell) then, m = -1, 0, +1

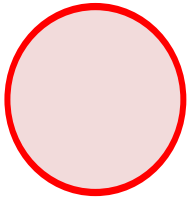
if l = 2 (d sub-shell) then, m = -2, -1, 0, +1, +2

if l = 3 (f sub-shell) then, m = -3, -2,-1, 0, +1, +2, +3

- It is clear that, the total values of m is equal to (2l + 1).

➢Each value of magnetic quantum number, m represents a definite orbital. Hence, total number of orbitals in a definite sub-shell, corresponds to the total values of m for respective sub-shell. For example,

For s- sub-shell (l = 0), there is only one value of m i.e. 0. Hence, s-sub-shell contains only one orbital called s- orbital.



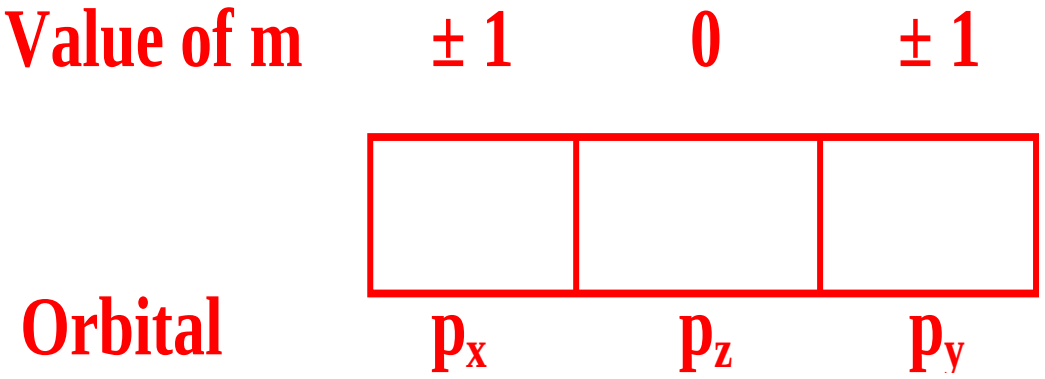
l = 0

m = 0

s-orbital

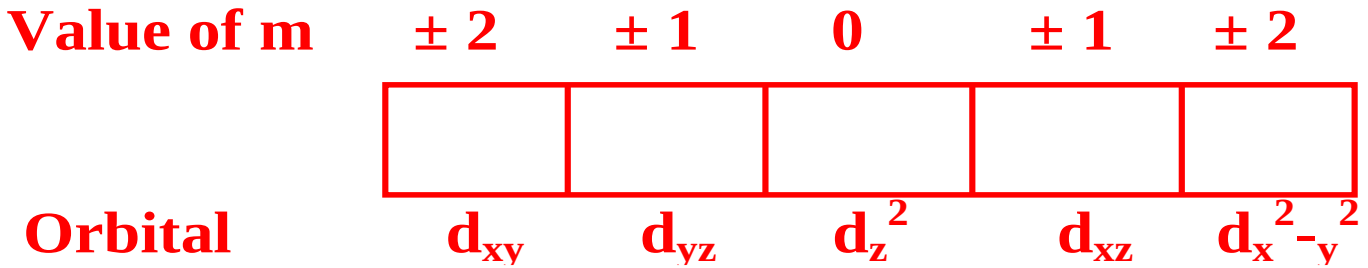
s- Subshell (l = 0)

➢For p- sub-shell (l = 1), there are three values of m i.e. -1, 0, +1. Hence, p-sub-shell contains three p-orbitals, namely p_x , p_z and p_y orbitals respectively.



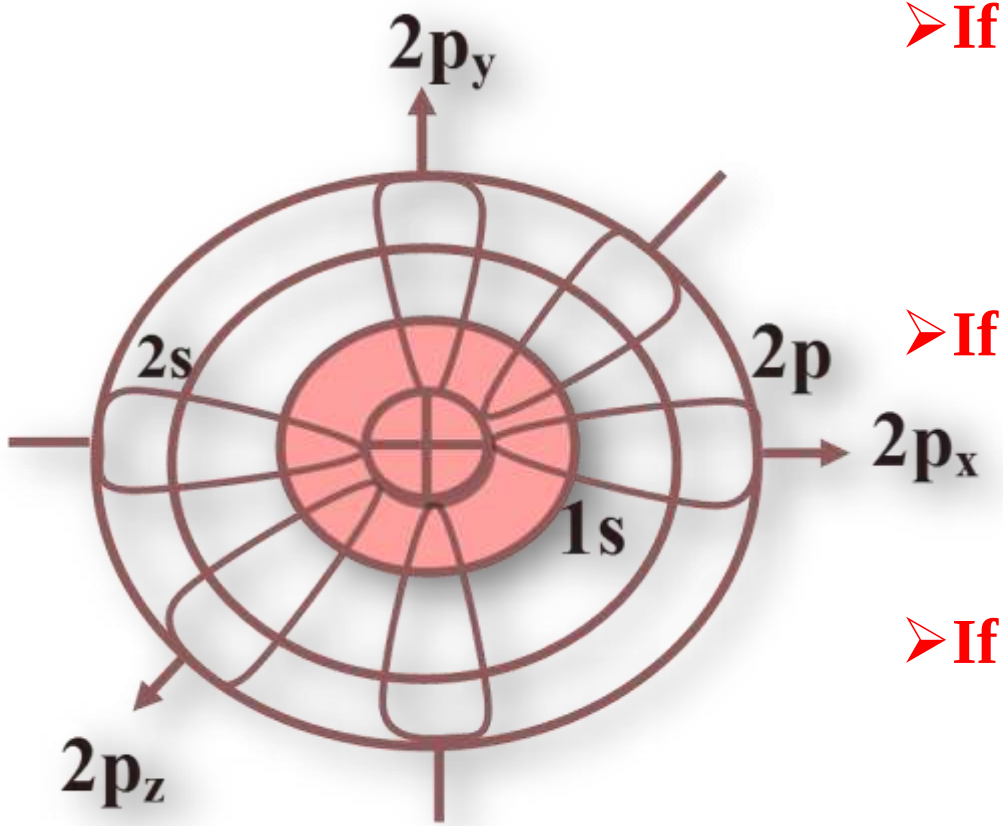
p- Subshell (l = 1)

0, +1, +2. Hence, d-sub-shell will contains five d- orbitals, namely d_{xy} , d_{yz} , d_z^2 , d_{xz} and $d_{x^2-y^2}$ orbitals respectively.



d- Sub-shell

- Similarly, f-sub-shell having seven values of m, contains seven f-orbitals.
- Magnetic quantum number, m also represents the orientation of orbitals in magnetic field. Hence, it is also called **orientation quantum number**.



Orbitals of 1s, 2s & 2p-Subshell

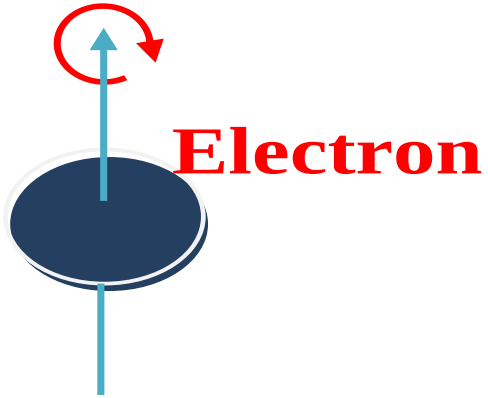
- **If for an electron-**
  - **n = 2**
  - **l = 0**
  - **m = 0**
- **If for an electron-**
  - **n = 2**
  - **l = 1**
  - **m = 0**
- **If for an electron-**
  - **n = 3**
  - **l = 2**
  - **m = +1**

(4)Spin Quantum number (s)

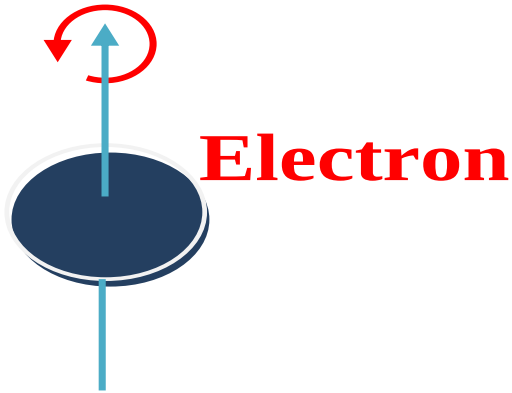
- This quantum number represents the direction of spin electron in an orbital.
- It is denoted by “s”.
- Since, electrons can either have clockwise or anti-clockwise spin, the spin quantum number, s can have only two values i.e.

+1/2 (for clockwise spin)

and -1/2 (for anti-clockwise spin).

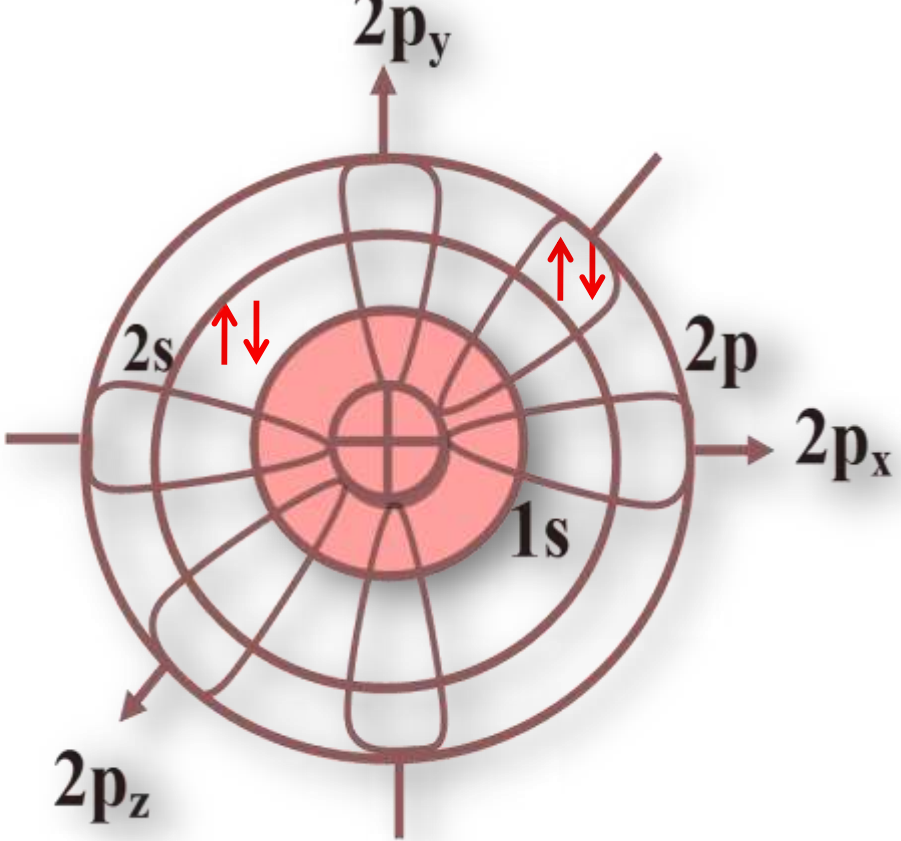


Clockwise spin
s = + 1/2



Anti-clockwise spin
s = - 1/2

Fig.- Different Types of Spin of Electron



Orbitals of 1s, 2s & 2p-Subshell

- **If for an electron-**
  - **n = 2**
  - **l = 0**
  - **m = 0**
  - **s = +1/2**
- **If for an electron-**
  - **n = 2**
  - **l = 1**
  - **m = 0**
  - **s = -1/2**

➢If for an electron-

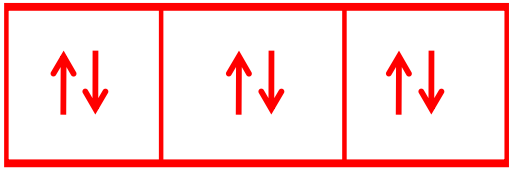
n = 2

l = 1

m = +1

s = -1/2

Value of m: ±1 0 ±1



Orbital: p_x p_z p_y

➢If for an electron-

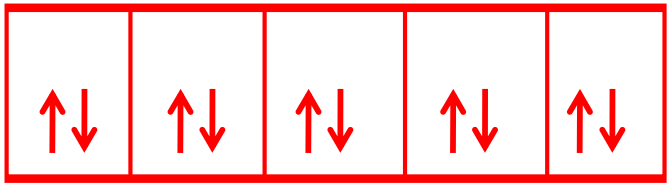
n = 3

l = 2

m = +1

s = +1/2

Value of m: ±2 ±1 0 ±1 ±2



Orbital: d_{xy} d_{yz} d_z^2 d_{xz} $d_{x^2-y^2}$

- If for an electron-

n = 2

l = 2 (Wrong address)

m = +1

s = -1/2

- If for an electron-

n = 2

l = 1

m = +2 (Wrong address)

s = -1/2

To Purchase PPTs for Online Classes/Making YouTube Videos or Video Book WhatsApp at:- 7389757666

Download pdf at-

www.chemistryforcompetition.com

Or

www.exacademy.in

For Video lectures visit- "Exacademy" YouTube channel

Download Mobile App "Exacademy" from Google App Store