By
Dr. Arun Kumar Pandey

Q:- What is Quantum numbers? Discuss its Significance.

Ans:- The state of electron in an atom is described by its location with respect to the nucleus and by its energy also. Thus energy and angular momentum of an electron are quantized. It means an electron in an atom can have only certain permissible values of its energy and angular momentum. These permissible states of electron in an atom are called Orbitals are identified by a set of four Numbers These numbers are called Quantum Numbers.

i.e. Quantum Numbers are the numbers which can provide the full information about the revolving electron around the nucleus in an atom.

The Quantum Numbers are as follows

Quantum Numbers:- (1) Principal (2) Azimuthal (3) Magnetic (4) Spin and its

Symbol :- n , l , m , s

(1) Principal quantum number (n) :- It determines the main energy level or shell in which the electron in an atom is present and also the energy associated with it.

It also determines the average distance of electron from the nucleus in a particular shell or Orbit.

These energy shells are denoted as K, L, M, N ----or, 1, 2, 3, 4-- etc.

The maximum number of electrons which a shell can accommodate is $2n^2$.

For example;- Total number of electron or Maximum number of electrons accommodated in K shell or 1st shell (i.e $n=1$)

$= 2 \times n^2 = 2 \times 1^2 = 2$, i.e TWO electrons

Similarly in L shell i.e $n = 2$

Maximum number of electrons present in L shell $= 2 \times 2$

$= 2 \times 4 = 8$ (Eight Electrons)

In M shell i.e $n = 3$

Maximum number of electrons present in M shell $= 2 \times 3^2$

$= 2 \times 9 = 18$ electrons

(2) Azimuthal or angular Quantum number (l) :- Azimuthal Quantum number determines the angular momentum of electron. This is denoted by l. The value of l gives principal energy shell in which electron belongs. The value of l hangs from zero to $(n-1)$.

Where n is Principal Quantum number.

i.e. $l = 0, 1, 2, 3, 4 \ldots\ldots (n-1)$

This fact may be tabled as follow.

Value of n	Value of l	Number of Orbital or Sub-shell	Name of the Sub-shell or Orbital
$n = 1$	0 to $(n-1) = 0$ to $(1-1) = 0$	One	s
$n = 2$	0 to $(n-1) = 0$ to $(2-1) = 0, 1$	TWO	s & p
$n = 3$	0 to $(3-1) = 0$ to $(3-1) = 0, 1, 2$	Three	s, p, & d
$n = 4$	0 to $(4-1) = 0$ to $3 = 0, 1, 2, 3$	Four	s, p, d, & f

Note!- Maximum number of electrons in an Orbital or Sub-shell is given by $(4l+2)$ where l is Azimuthal Quantum number i.e. 0, 1, 2, 3 for s, p, d, and f Sub-Shells or Orbitals.

(3) Magnetic Quantum Number :- Magnetic quantum Number defines the behaviour of an electron in magnetic field and it is denoted by m. For a given value of l, the value of m varies from $-l$ to $+l$.

For example the value of l is 0 (zero) then the value of m is $-l$ to $+l$ i.e -0 to $+0$ i.e 0 (zero).

l value is 0 (zero)

then m value is 0 (zero)

2nd Example :- The Value of l is 1 (one).

Then the value of m is $-l$ to $+l$

i.e $-1, 0, +1$ (Three values of m)

It means for a given value of l the total value of m is $(2l+1)$

3rd Example :- If the value of l is 2 (TWO)

Now m value is -2 to $+2$

i.e $-2, -1, 0, +1, +2$

If $l = 2$, Total m value is $(2l+1) = (2 \times 2 + 1) = 5$ (Five)

4the Example :- If the value of l is 3 (three)

'm' value is $-l$ to $+l$

i.e -3 to $+3$

or, $-3, -2, -1, 0, +1, +2, +3$

~~In this Case l value is 3, so total m values are $(2l+1) =$~~

These Seven values are $-3, -2, -1, 0, +1, +2, +3$

The above facts may be summarised in the following chart given below or the numbers of orbitals in different sub-shell are as follows

Value of l	Value of m	Name of Sub-shell	Orientation of Sub. Name of the Orbitals
0	$m = 0$	's' - Sub-shell	One 's' orbital
1	$m = -1, 0, +1$	p - Sub-shell	Three 'p' orbital i.e p_x, p_y & p_z
2	$m = -2, -1, 0, +1, +2$ Total = 5 values	d - Sub-shell	Five d orbitals i.e, d_{xy}, d_{yz}, d_{xz}, d_{x^2}
3	$m = -3, -2, -1, 0, +1, +2, +3$ Total = 7 values	f - Sub-shell	Seven 'f' orbitals i.e, f_1, f_2 f_3 f_4, f_5 It's structure is

Spin Quantum number: Spin quantum number describes the spin of the electron. It is designated by 's'.

Since the moving electron can spin in two only, One is clockwise and another anticlockwise, so spin Quantum number can take only two values $+1/2$ and $-1/2$. It is represented by two arrows whose points are in the opposite direction.

i.e ↑ & ↓

———— x ————