ATOMIC PHYSICS

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VECTOR ATOM MODEL

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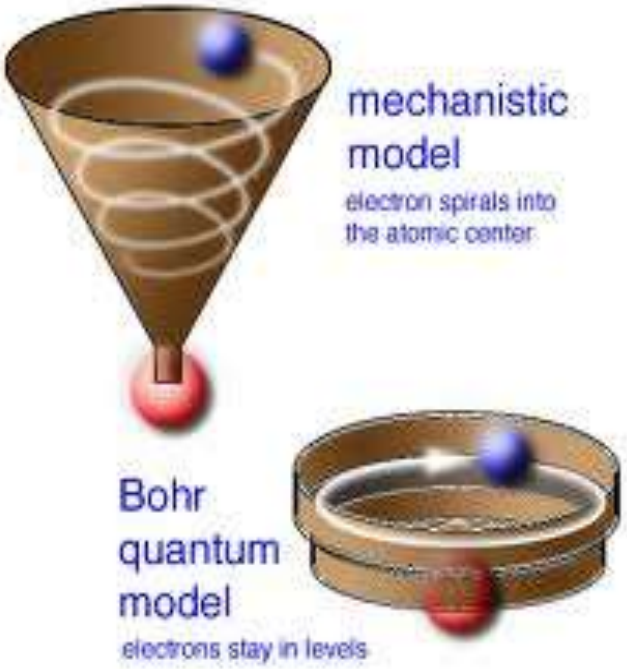
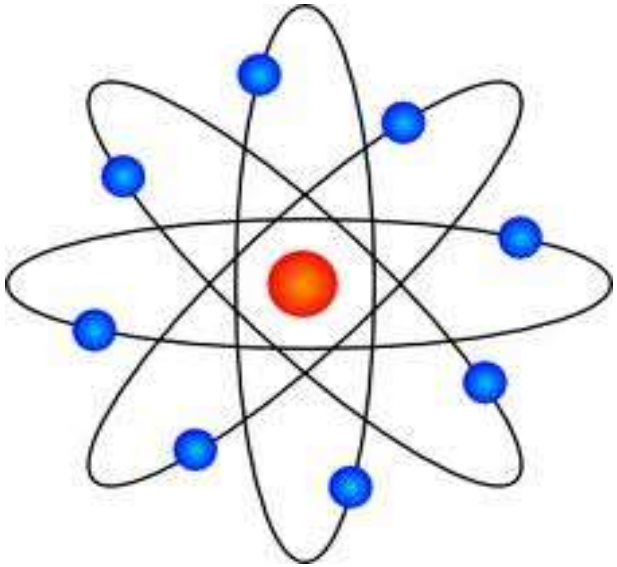
is an extension of the

Bohr- Sommerfield atom model.


mechanistic
model
electron spirals into
the atomic center
Bohr
quantum
model
electrons stay in levels



Following are the short-comings of Bohr-Sommerfield atom model.

1. It could not explain the ‘fine structure’ of spectral lines.
2. It could not explain the distribution and arrangement of electrons in atoms.
3. It could not explain Zeeman Effect and Stark Effect .

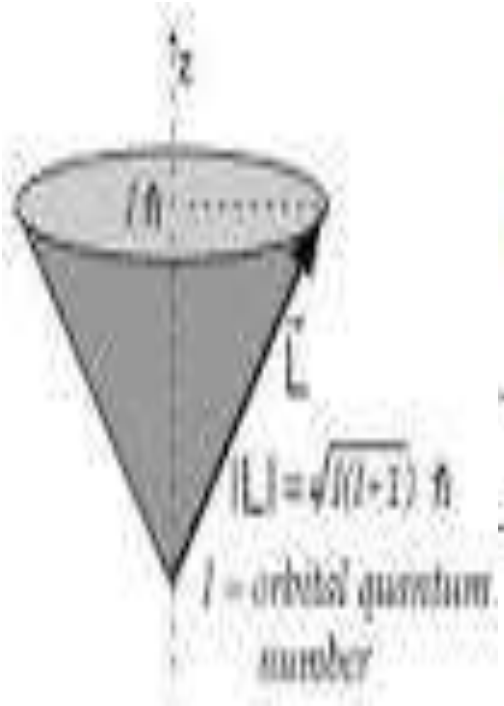
To overcome all these objections, a new model known as VECTOR ATOM MODEL was proposed.

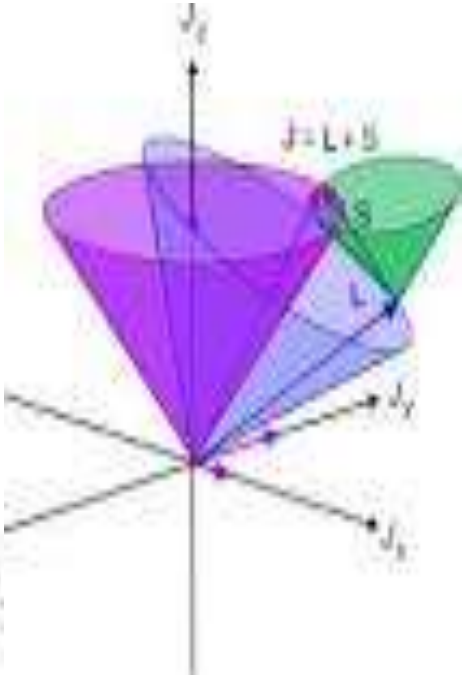
- The two distinct features of the **VECTOR ATOM MODEL** are

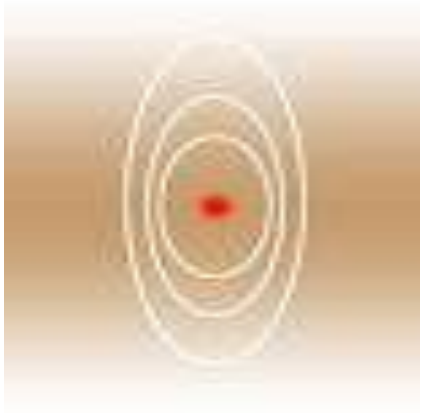
- The concept of spatial quantization or the quantization of direction.

- The concept of spinning electron.

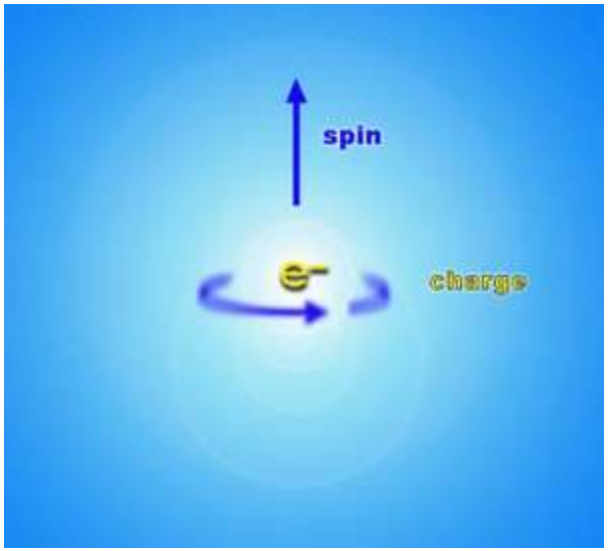
VECTOR ATOM MODEL

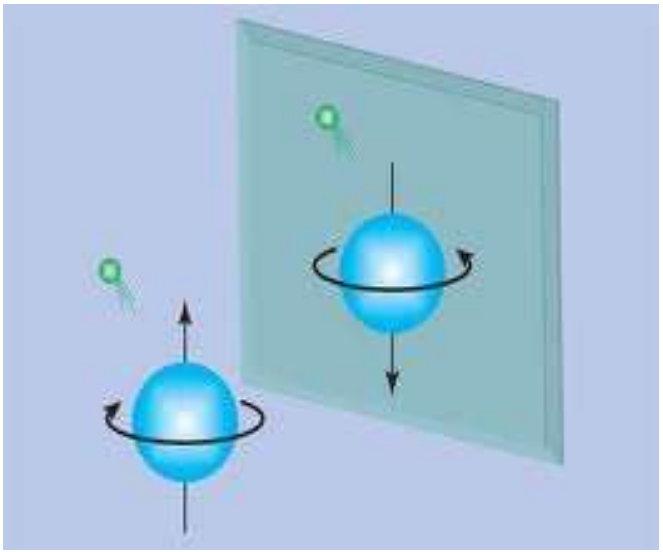


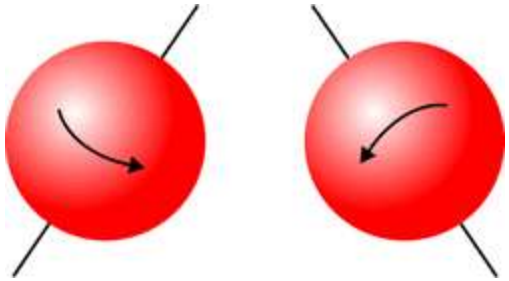


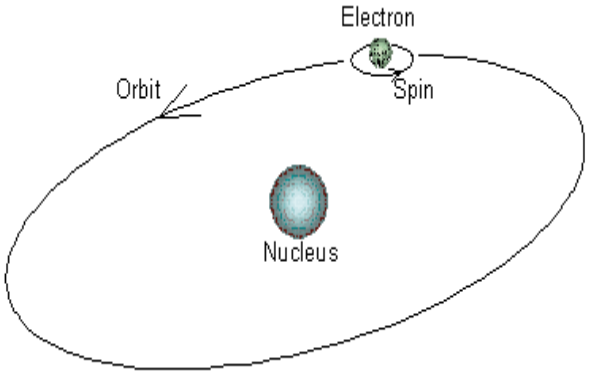


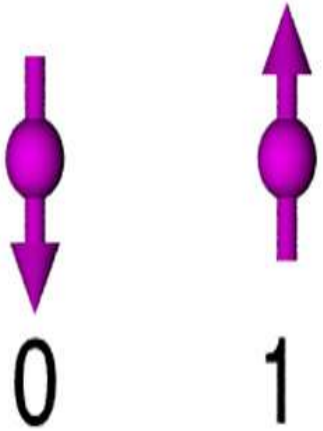
SPINNING ELECTRON









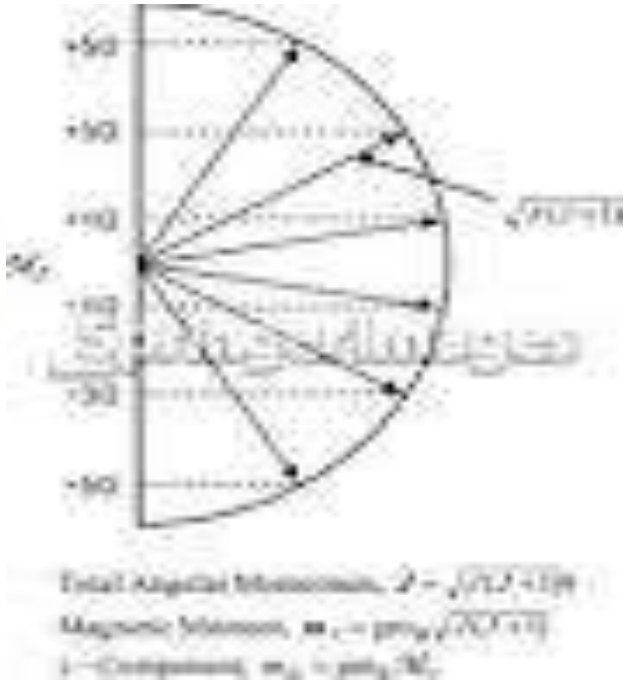


Binary information (0 or 1) can be stored in the physical state of an electron (spin down or spin up).

Spatial quantization

- According to Bohr's theory, the orbits are quantized as regards their *magnitude* (ie., their size and form) only.
- But according to quantum theory, the *direction* or orientation of the electron orbits in space, also should be quantized.
- To specify the orientation of the electron orbit in space, we need a fixed reference axis.
- The reference line is chosen as the direction of an external magnetic field that is applied to the atom.
- The different permitted orientations of an electron orbit are determined by the fact that *the projections of the quantized orbits on the field direction must themselves be quantized.*

Spatial quantization



- The introduction of such a spatial quantization does not change the size or shape of the Bohr-Sommerfield orbits but makes the orbits vector quantities.

2.SPINNING ELECTRON:

- The electron spins about an axis of its own, while it also moves round the nucleus of the atom in its orbit.
- In other words, the electron is endowed with a spin motion and an orbital motion.

- According to the quantum theory, the spin of the electron also should be quantized.
- Hence a new quantum number called the spin quantum number (s) is introduced.
- the spin endows the electron with a spin angular momentum sñ and a spin magnetic moment.
- Hence the total angular momentum of an atom should be the vector sum of the orbital angular momentum and spin angular momentum.
- Similarly, the total magnetic moment of an atom should be the vector sum of the orbital and spin magnetic moments.

- The orbital and spin motions are both quantised in magnitude and direction according to the idea of spatial quantisation. So they are considered as quantised vectors.
- Hence the atom model based on these quantised vectors is called the **“VECTOR ATOM MODEL”.**

QUANTUM NUMBERS ASSOCIATED WITH THE VECTOR ATOM MODEL

1.The Principal quantum number (n)

2.The Orbital quantum number (l)

3. The Spin quantum number (s)

4.Total angular momentum quantum number (j)

5.Magnetic Orbital quantum number (m_l)

6. Magnetic Spin quantum number (m_s)

7. Magnetic total angular momentum quantum number (m_j)

1.The Principal quantum number (n)

- The serial number of the shells starting from the innermost is designated as its **Principal quantum number (n).**
- It can take only integral values excluding zero. ie., n=1,2,3,4…..

2.The Orbital quantum number (l)

- This quantum number defines the shape of the orbital occupied by the electron and the **orbital angular momentum** of the electron.
- This may take any integral values, 0,1,2,3….,(n-1).
- Thus ,if n=4, l can take the four values 0,1,2,3.

- By convention, an electron for which

l=0, is called ***s*** electron;

if l=1 ***p*** electron=2,

d electron;

l=3, ***f*** electron etc.

- the ***orbital angular momentum*** p_l of the electron is given by $p_l = l\tilde{n}$.
- *According to wave mechanics,*

$\mathcal{P}_l = [\, l(l+1)]^{1/2}\tilde{n}$

3. The Spin quantum number (s)

- This has only one value, s=1/2.
- The Spin angular momentum p_s=s ñ Where s=1/2
- According to wave mechanics,

$p_s = [\ s(s+1)]^{1/2}$ñ

Since the electron can spin clockwise or anti clock wise, s has two values, +1/2 and -1/2.

Two electrons with same sign of spin quantum number are said to have parallel spins.

Two electrons with opposite sign of spin quantum number are said to have opposite spins or paired up spins.

4.Total angular momentum quantum number (j)

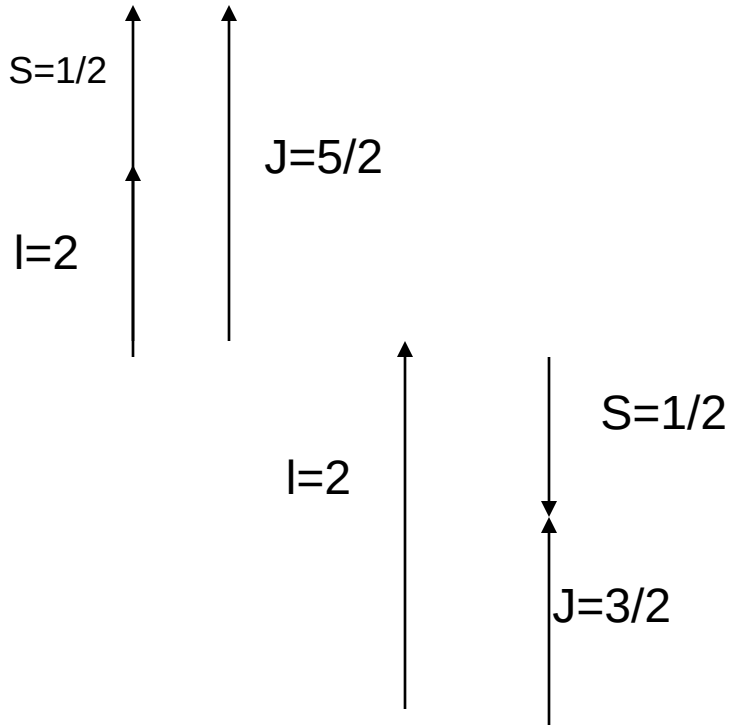
- It represents the total angular momentum of the electron.
- It is the sum of the **orbital angular momentum and Spin angular momentum .**
- The vector j is defined by the equation $\vec{j} = \vec{l} + \vec{s}$ with the restriction that j is positive.
- **The Spin angular momentum s = + ½ or -1/2.**
- j = l + s, plus sign when s is parallel to l and
- j = l – s, minus sign when s is antiparallel to l.
- Thus for l=2 and s=1/2, j can have the values 5/2 and 3/2.

total angular momentum of the electron

$p_j = j\,\tilde{n}$.

- *According to wave mechanics,*

$p_j = [\, j(j+1)]^{1/2}\tilde{n}$.fig.

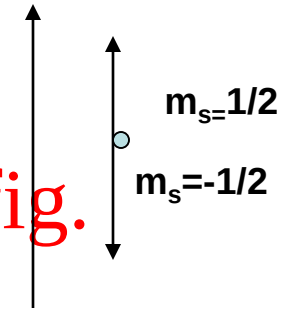


5.Magnetic Orbital quantum number (m_l)

- The projection of the orbital quantum number l on the magnetic field direction is called the **Magnetic Orbital quantum number (m_l)**
  the possible values of $\mathbf{m_l}$ are l, l-1,l-2,….0,-1,-2,….-l.
- $\mathbf{m_l}$ may have any of the (2l+1) values from –l to +l including zero.

6. Magnetic Spin quantum number (m_s)

- This is the projection of the spin vector s along the direction of the magnetic field.
- The spin angular momentum (s) can assume only two possible positions with respect to the magnetic field.
- It may be parallel to it or antiparallel.
- **M_s** can have only two values +1/2 or -1/2.fig.



7. Magnetic total angular momentum quantum number (m_j)

- This is the projection of total angular momentum vector j on the direction of the magnetic field.
- J can have only odd half-integral values (j=l+1/2, j=l-1/2).
- Hence, $\mathbf{m_j}$ can have only (2j+1) values, from +j to-j, zero excluded.

THE PAULI EXCLUSION PRINCIPLE

STATEMENT:

- *No two electron in an atom exist in the same quantum state.*
- *The four quantum numbers n, l, m_l, m_s determine the state of an electron completely.*
- *"no two electron in an isolated atom may have the same four quantum numbers*