Electron Spin

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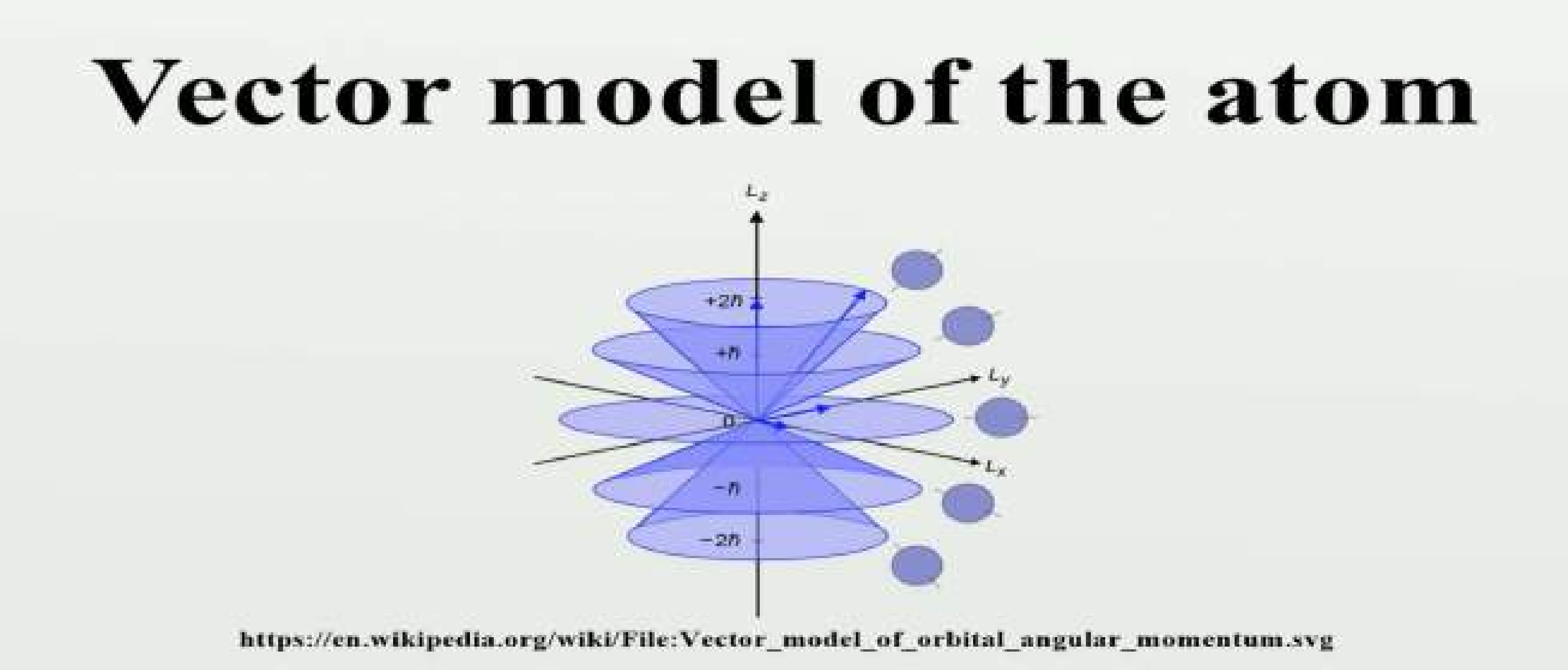
Limitations of Bohr -Summer field Model

Limitation of Bohr-Sommerfeld model

1. Unable to explain-the multiplet structure of line of alkali spectra.
2. Unable to explain-Anomalous Zeeman effect and Stark effect.
3. Atomic model proposed by Bohr Sommerfeld are for two dimensional entity.

Vector Atom Model



Vector atom model

- Dutch Physicists George E.Uhlenbeck and Samuel Goudsmit in 1925, extended Bohr - Sommerfeld model and proposed Vector atom model. This model is base on two concept-

1. Spining of electron
2. Spacial quantization.

Spining of electron

Electron not only rotate about the nucleus but also about its own axis . Spin is a quantum feature of electron. Spin is quantized in the same manner as orbital angular momentum. It has been found that the magnitude of the intrinsic spin angular momentum *S* of an electron is given by

$$S = \sqrt{s(s+1)}\ \frac{h}{2\pi}$$

where *s* is defined to be the spin quantum number.

Space quantization.

- In an atom the motion of the electron is in three dimensional. As per Sommerfeld model to deal with three degree of freedom we require three quantum numbers.
- Atom in a magnetic field whose quantum states correspond to a limited number of possible angles between the directions of the angular momentum and the magnetic intensity, this concept is known as the space quantization.

Space quantization and angular momentum

The Bohr model postulates for orbital angular momentum:
$L = lh/2\pi$, where l is **orbital angular quantum number.**
l=0,1,2,3,.....(n-1). Where n is **principal quantum number.**

We assume that a similar relation also holds for Lz i.e.
Lz runs from −l to +l : $Lz = m_l\, h/2\pi$ with $m_l = -l, -l+1, .., 0, .. l-1, l$. The number m_l is called **magnetic quantum number** .
This type of quantization of the component Lz of angular momentum L is called **space quantization.**

Different types quantum numbers

- Principal quantum number, n.
- Orbital angular momentum quantum number, l.
- Magnetic quantum number, m_l.
- Electron spin quantum number, m_s.
- Total angular quantum number, j.

Quantum Numbers

Schrödinger's approach uses three quantum numbers (n, l, and m_l) to specify any wavefunction. The quantum numbers provide information about the spatial distribution of an electron. Although n can be any positive integer, only certain values of l and m_l are allowed for a given value of n.

The Principal Quantum Number

The **principal quantum number** (n) tells the average relative distance of an electron from the nucleus:

n=1,2,3,4,………… Etc.

As n increases for a given atom, so does the average distance of an electron from the nucleus. A negatively charged electron that is, on average, closer to the positively charged nucleus is attracted to the nucleus more strongly than an electron that is farther out in space. This means that electrons with higher values of n are easier to remove from an atom. All wavefunctions that have the same value of n are said to constitute a principal shell because those electrons have similar average distances from the nucleus.

The Azimuthal Quantum Number

The second quantum number is often called the **azimuthal quantum number (l)**. The value of *l* describes the *shape* of the region of space occupied by the electron. The allowed values of *l* depend on the value of *n* and can range from 0 to *n* – 1:

$$l=0,1,2,\ldots, n-1$$

For example, if *n* = 1, l can be only 0; if *n* = 2, l can be 0 or 1; and so forth. For a given atom, all wavefunctions that have the same values of both *n* and l form a subshell. The regions of space occupied by electrons in the same subshell usually have the same shape, but they are oriented differently in space.

The Magnetic Quantum Number

The third quantum number is the magnetic quantum number (m_l). The value of m_l describes the *orientation* of the region in space occupied by an electron with respect to an applied magnetic field. The allowed values of m_l depend on the value of l: m_l can range from $-l$ to l in integral steps:

$$m_l = -l, -l+1, \ldots, 0, \ldots, l-1, l$$

For example, if $l=0$, m_l can be only 0; if $l = 1$, m_l can be $+1, 0 . -1$, and if $l = 2$, m_l can be $-2, -1, 0, +1, +2$.

Each wavefunction with an allowed combination of n, l, and m_l values describes an atomic **orbital**, a particular spatial distribution for an electron. For a given set of quantum numbers, each principal shell has a fixed number of subshells, and each subshell has a fixed number of orbitals.

Quantum Numbers:

Quantum numbers provide important information about the energy and spatial distribution of an electron. The **principal quantum number** n can be any positive integer; as n increases for an atom, the average distance of the electron from the nucleus also increases. All wavefunctions with the same value of n constitute a **principal shell** in which the electrons have similar average distances from the nucleus. The **azimuthal quantum number** l can have integral values between 0 and $n - 1$; it describes the shape of the electron distribution. wavefunctions that have the same values of both n and l constitute a **subshell**, corresponding to electron distributions that usually differ in orientation rather than in shape or average distance from the nucleus. The **magnetic quantum number** m_l can have $2l + 1$ integral values, ranging from $-l$ to $+l$, and describes the orientation of the electron distribution. Each wavefunction with a given set of values of n, l, and m_l describes a particular spatial distribution of an electron in an atom, an **atomic orbital**.

Angular momentum quantum number

the orbital angular momentum of the electron is quantized, and its magnitude is

$$L = \sqrt{l(l+1)}\ h/2\pi$$

where l is the angular momentum quantum number, and it describes the shape of a given orbital. The value of l is

l=0,1,2,3,.....(n- 1).

- Orbital angular momentum quantum number, can indicate by s, p, d, or f sub shell which vary in shapes.

Spin quantum number

Spin angular momentum of the electron is quantized in the same manner as the orbital angular momentum of the electron . The magnitude of the intrinsic spin angular momentum *S* of an electron is given by

$$S = \sqrt{s(s+1)}\ \frac{h}{2\pi}$$

Where s is known as **Spin quantum number** . For all electrons, however, $s = ½$. A number m_s gives the projection of the spin angular momentum, known as **spin magnetic quantum number**. The possible values of m_s are $-s$ and s. Hence for an electron in an atom, m_s can be either -½ or +½.

Total angular momentum quantum number

Total angular moment **J** is the vector sum of **L** and **S**

$$\mathbf{J} = \mathbf{L} + \mathbf{S}$$

total angular momentum **J** is quantized in both magnitude and direction . The magnitude of **J** is given by

$$J = \sqrt{j(j+1)} \quad h/2\pi$$

where $j = l \pm s$ $(l \neq 0)$, if $l=0$, then $j=1/2$.

j is know as **total quantum number**. The component of J_z of J in the z direction is given by $J_z = m_z\, h/2\pi$.

$m_z = -j, -j+1 \ldots 0 \ldots j+1, j.$, m_z is know as **total magnetic quantum number**.

References:

1. Raj Kumar, Atomic and Molecular Spectra: Laser, Kedear Nath Publication, Meerut, 2015
2. Arthur Beiser, Concepts of Modern Physics, 6th ed.,McGraw Hill, New Delhi, 2008.
3. Harvey Elliott White, Introduction to Atomic Spectra, McGraw Hill, 1963.
4. G M Barrow, Introduction to molecular spectroscopy, Tata McGraw Hill,Japan, 1962.
5. Internet