



The Magnetism from the Movement of Electron in Hydrogen Atom

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

In this work we calculated the magnetism from the movement of electron in hydrogen atom and found that the contributions from the electron in the same main quantum levels to the magnetism of the hydrogen atom are the same; but the contributions from the electron in different main quantum levels to the magnetism of the hydrogen atom are the eigenvalue dependent instead. These facts tell us that the concepts about "intrinsic property" and "relativity effect" of electron spin should be discarded, and accordingly, the quantum mechanics should be rebuilt.

Keywords: Magnetism; electron Spin; intrinsic property; relativity effect; magnetic momentum.

1. INTRODUCTION

One of most important discoveries of the human being is the phenomenon of the electricity and magnetism. The effort of the human being in understanding the electricity and magnetism can be divided into two stages.

At the first stage, the researchers focus on the relation between the electricity and magnetism in

macro-scale. H. C. Ørsted found that the electricity can create the magnetism [1]. Then, M. Faraday and J. Henry discovered the reverse process, that is, using magnet to generate the electricity and proposed the principle of electromagnetic induction [2-3]. In this process, a series of famous scientists made their contributions for the human being to understand the electricity and magnetism, such as C.

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Coulomb, A. M. Ampere, and C. F. Gauss and many more [4-6].

Later on, J. Maxwell combined all the knowledge obtained by the human being regarding the electricity and magnetism into a group of equations, called Maxwell equations, which unified the electricity, magnetism and optics into the field of electromagnetism [7]. Based on the understanding of the electricity and magnetism, A. Einstein setup the theory of special relativity [8].

At macro-scale, the knowledge regarding the electricity and magnetism made the birth of the electricity generator, telecommunication and naval navigation, etc. Now we can say the application of the electricity and magnetism already fused into our daily life.

At the second stage, the character of the human being is to pursue the mechanism regarding the phenomenon observed in the nature. For the electricity and magnetism, the researchers try to elucidate at the micro-scale instead of just stopping at the explanation at the macro-scale. This kind of curiosity of the human being leads to a series of discoveries, such as the atom, electron, neutron and proton, etc [9-12]. These new discoveries made the knowledge of the human being increase like the Volcano bursting out. This explosive increase of knowledge started from the beginning of last century. We can cite a series of famous scientists who made great contributions to this knowledge explosively increasing, such as M. Planck, A. Einstein, E. Schrödinger, P. Dirac, M. Born, W. Heisenberg, N. Bohr, W. Pauli [13-20] and finally, a new field was setup, that is, the quantum mechanics [21]. Since then, most of phenomenon observed in the nature, including the electricity and magnetism, can be explained clearly at the micro-scale.

Now, the quantum mechanics becomes the essential tool for scientists to understand the physical process going on in the nature, from the macro-scale to micro-scale.

In this work, we will use the current knowledge regarding the electricity and magnetism to explore the mechanism of the magnetism created from the movement of electron in the atom.

2. THEORETICAL CALCULATION AND DISCUSSION

In order to simplify our discussion, we take the hydrogen atom as an example here. Table 1 lists

the wave function of the hydrogen atom from the solution of the Schrödinger's equation [22].

For the hydrogen atom, $Z=1$; a is the Bohr radius.

From the work of M. Faraday [23], we know that the moving charge will create the magnetic field around the charge, which can be described by

$$B = \frac{\mu_0 I}{2\pi r} \quad (1)$$

Where B is the magnetic field; μ_0 is the permeability of free space; I is the current; r is the radial distance from the centre around which the electron turns (here it is the proton).

For the electron turns around the proton in the hydrogen atom, for example, the electron in φ_{1s} orbital,

$$dB = \frac{\mu_0 I}{2\pi r} d\tau \quad (2)$$

Where $I = e \frac{d(\varphi_{1s}(r)\varphi_{1s}^*(r)\varphi_{1s}(t)\varphi_{1s}^*(t))}{dt}$, here e is the elementary charge of electron; $\varphi_{1s}(t) = e^{-i\frac{E_{1s}}{\hbar}t}$; E_{1s} is the eigen value of electron in φ_{1s} ; \hbar is the reduced Planck constant; t is the time.

$$\begin{aligned} B_{1s} &= \int_0^\infty \frac{\mu_0 e \varphi_{1s}^2(r) \frac{d(\varphi_{1s}(t)\varphi_{1s}^*(t))}{dt}}{2\pi r} d\tau \\ &= \int_0^\infty \frac{\mu_0 e \varphi_{1s}^2(r) \left(\frac{iE_{1s}}{\hbar} - i\frac{E_{1s}}{\hbar} \right)}{2\pi r} d\tau \\ &= \int_0^\infty \frac{\mu_0 e \varphi_{1s}^2(r) \frac{E_{1s}}{\hbar} (i-i)}{2\pi r} d\tau \\ &= 1.9923(i-i)(T) \end{aligned} \quad (3)$$

If we define $(i-i)$ as ``hidden`` factor or ``dark`` factor, then,

$$B_{1s} = 1.9923\Delta (T), \text{ where } \Delta = (i-i).$$

In point of view of mathematician, the B_{1s} is just zero but for physicist, the result of B_{1s} has meaning more than just zero. This case can be illustrated in Fig. 1. For the hydrogen atom at the ground state, it doesn't show the magnetism. Our calculation above supports this conclusion. However, our calculation result also tells us that under special case, for example, the applied inhomogeneous magnetic fields, the hydrogen atom at the ground state will show the interaction between the hydrogen atom and the applied inhomogeneous magnetic field. This

interaction will split the electron energy state from one into two. This point has been verified by the Stern-Gerlach's experiment [24]. The harmonic consistency of the different behaviors of the hydrogen atom under free condition and the inhomogeneous magnetic field is realized by the "hidden" factor or "dark" factor (See Fig.1).

It is very interesting to take a look how to solve this contradictory between the experimental result and theoretical calculation from the quantum mechanics in the literatures [25]. For the theoretical scientists, they solve this contradictory by adding an extra term onto the wave function from the solution of Schrödinger's equation, called the electron spin term. This means that the magnetic field of hydrogen atom at the ground state comes from the electron spinning in the hydrogen atom. But this scheme of solution causes another problem, that is, the electron should keep spinning around its own axis. However, to our knowledge, experimentally we can't determine the volume of electron [26], then, some scientists suppose

the electron has no volume. The question is, if the electron has no volume, how it turns around its own axis and how to determine its axis? In the end, they assign the magnetic field of hydrogen atom at the ground state coming from the "intrinsic property" of electron; some scientists call this phenomenon as the "relativity effect" of electron.

Based on our calculation and understanding, the different behaviors of the hydrogen atom under free condition and the applied inhomogeneous magnetic fields can be explained quite well (see Fig.1). The space point around the proton in hydrogen atom, under free condition, doesn't show any magnetism, but under the applied inhomogeneous magnetic fields, each space point, due to the movement of the electron in the hydrogen atom, will show the magnetic interaction between the space point around the proton in the hydrogen atom and the applied inhomogeneous magnetic fields, which will cause the splitting of the energy level of electron in the hydrogen atom from one into two.

Table 1. The Real Hydrogen-like Wave Function

$\varphi_{1s} = \frac{1}{\pi^{1/2}} \left(\frac{Z}{a}\right)^{3/2} e^{-Zr/a}$
$\varphi_{2s} = \frac{1}{4(2\pi)^{1/2}} \left(\frac{Z}{a}\right)^{3/2} \left(2 - \frac{Zr}{a}\right) e^{-Zr/2a}$
$\varphi_{2pz} = \frac{1}{4(2\pi)^{1/2}} \left(\frac{Z}{a}\right)^{5/2} r e^{-Zr/2a} \cos\theta$
$\varphi_{2px} = \frac{1}{4(2\pi)^{1/2}} \left(\frac{Z}{a}\right)^{5/2} r e^{-Zr/2a} \sin\theta \cos\phi$
$\varphi_{2py} = \frac{1}{4(2\pi)^{1/2}} \left(\frac{Z}{a}\right)^{5/2} r e^{-Zr/2a} \sin\theta \sin\phi$
$\varphi_{3s} = \frac{1}{81(3\pi)^{1/2}} \left(\frac{Z}{a}\right)^{3/2} \left(27 - 18\frac{Zr}{a} + 2\frac{Z^2 r^2}{a^2}\right) e^{-Zr/3a}$
$\varphi_{3pz} = \frac{2^{1/2}}{81(\pi)^{1/2}} \left(\frac{Z}{a}\right)^{5/2} \left(6 - \frac{Zr}{a}\right) r e^{-Zr/3a} \cos\theta$
$\varphi_{3px} = \frac{2^{1/2}}{81(\pi)^{1/2}} \left(\frac{Z}{a}\right)^{5/2} \left(6 - \frac{Zr}{a}\right) r e^{-Zr/3a} \sin\theta \cos\phi$
$\varphi_{3py} = \frac{2^{1/2}}{81(\pi)^{1/2}} \left(\frac{Z}{a}\right)^{5/2} \left(6 - \frac{Zr}{a}\right) r e^{-Zr/3a} \sin\theta \sin\phi$
$\varphi_{3dz^2} = \frac{1}{81(6\pi)^{1/2}} \left(\frac{Z}{a}\right)^{7/2} r^2 e^{-Zr/3a} (3\cos^2\theta - 1)$
$\varphi_{3dxz} = \frac{2^{1/2}}{81(\pi)^{1/2}} \left(\frac{Z}{a}\right)^{7/2} r^2 e^{-Zr/3a} \sin\theta \cos\theta \cos\phi$
$\varphi_{3dyz} = \frac{2^{1/2}}{81(\pi)^{1/2}} \left(\frac{Z}{a}\right)^{7/2} r^2 e^{-Zr/3a} \sin\theta \cos\theta \sin\phi$
$\varphi_{3dx^2-y^2} = \frac{1}{81(2\pi)^{1/2}} \left(\frac{Z}{a}\right)^{7/2} r^2 e^{-Zr/3a} \sin^2\theta \cos 2\phi$
$\varphi_{3dxy} = \frac{1}{81(2\pi)^{1/2}} \left(\frac{Z}{a}\right)^{7/2} r^2 e^{-Zr/3a} \sin^2\theta \sin 2\phi$

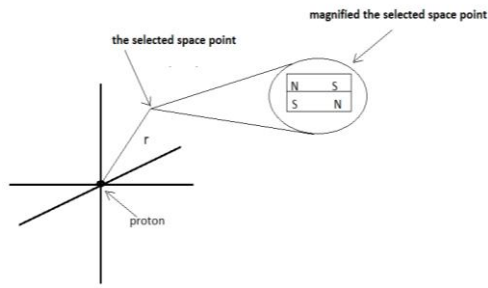


Fig. 1. The Illustration of the Space Point Structure around the Proton in the Hydrogen Atom

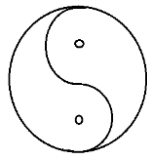


Fig. 2. The Tai Ji Picture Based on Yin and Yang Philosophy

This situation makes us recall that in the ancient time, Chinese thinkers proposed the “Yin” and “Yang” philosophy to explain the phenomenon observed in the nature [27]. Based on their philosophy, the universe is composed of two parts, that is, “Yin” and “Yang”. Their “Yin” and “Yang” philosophy also can be illustrated by the picture (Fig.2), which they called “Tai Ji” picture. Comparing “Tai Ji” picture with the magnetism at the space point around the proton in the hydrogen atom (Fig.1), they are almost the same. That means the “Yin” and “Yang” philosophy is indeed a fundamental principle in our universe.

From our discussion above, we can explain the magnetic behavior of the electron in the hydrogen atom quite well and don't need adding an extra term onto the wave function from the solution of Schrödinger's equation as traditionally doing in the literature. Here we can define $\Delta=i-i$

as “hidden” factor or “dark” factor. Due to the existence of this “hidden” factor or “dark” factor, it is guaranteed that under free condition, the hydrogen atom doesn't show the magnetic field and under the applied inhomogeneous magnetic fields, the hydrogen atom shows the interaction with the applied inhomogeneous magnetic fields, which causes the energy level of the electron in the hydrogen atom splitting from one into two. Therefore, the concept regarding the magnetism from the “intrinsic property” and the “relativity effect” of the electron in the hydrogen atom at the ground state should be discarded.

From our result above, we also may give the hint of the explanation of the phenomenon observed in our universe, such as “dark” energy and “dark” matter [28]. Since the concepts of “dark” energy and “dark” matter are proposed, nobody knows how and where we can search these “dark” stuffs. Till now there is no any direct experimental evidence found yet. Our result regarding the magnetic field of the hydrogen atom may offer a reasonable explanation about the “dark” energy and “dark” matter and correct guidance for the researchers to explore the “dark” energy and “dark” matter. Just like the observation of the magnetism of the electron in the hydrogen atom, if we hope to detect the “dark” energy, we should apply the inhomogeneous energy field or the inhomogeneous energy gradient onto the selected space point, then, we may observe the effect of the “dark” energy at the selected space point. In the same way, if we hope to detect “dark” matter, we have to apply the inhomogeneous matter field (or inhomogeneous gravity gradient) onto the selected space point, then we may observe the behavior of the “dark” matter at the selected space point.

Following the same procedure, we can calculate the magnetic field from the electron in different orbital of the hydrogen atom as at the ground state. Table 2 listed the part of results.

Table 2. The Contribution from the electron in different orbital to the Magnetic field of the Hydrogen atom

Wavefunction	Magnetic Field (Tesla)
φ_{1s}	$1.9923\Delta(T)$
$\varphi_{2s}, \varphi_{2p}$	$0.1245\Delta(T)$
$\varphi_{3s}, \varphi_{3p}, \varphi_{3d}$	$0.07379\Delta(T)$

** Δ is the “hidden” factor or “dark” factor*

From the data listed in Table 2, these points should be stressed here.

1. Among the wavefunctions of the hydrogen atom from the solution of Schrödinger's equation (Table 1), only the electron in φ_{1s} of hydrogen atom can be identified as "pure" electron spin making the contribution to the magnetic field of the hydrogen atom, all other wavefunctions more or less have the radial orbital movement contribution mixed in, including the ns orbital ($n>1$). We take φ_{2s} as an example here,

φ_{2s} can be written as

$$\varphi_{2s} = \frac{1}{4(2\pi)^{1/2}} \left(\frac{1}{a}\right)^{3/2} 2e^{-r/2a} - \frac{1}{4(2\pi)^{1/2}} \left(\frac{1}{a}\right)^{3/2} \frac{r}{a} e^{-r/2a} \quad (4)$$

The first term is similar to φ_{1s} , only difference is the constant, therefore, the first term can be taken as "pure" electron spin, while the second term, in which the coefficient is not constant, can be called as "orbital" or partly be contaminated by orbital movement of electron. Totally, the electron in φ_{2s} can't be considered as "pure" spin of electron like the electron in φ_{1s} . Based on this analysis, we can split the contribution to the magnetic field of the hydrogen atom from the electron in φ_{2s} into three parts,

$$\varphi_{2s1}^2 = \left[\frac{1}{4(2\pi)^{1/2}} \left(\frac{1}{a}\right)^{3/2} 2e^{-r/2a} \right]^2 \quad (5)$$

$$\varphi_{2s1-2}^2 = -\frac{4r}{a} \left[\frac{1}{4(2\pi)^{1/2}} \left(\frac{1}{a}\right)^{3/2} e^{-r/2a} \right]^2 \quad (6)$$

$$\varphi_{2s3}^2 = \left[-\frac{1}{4(2\pi)^{1/2}} \left(\frac{1}{a}\right)^{3/2} \frac{r}{a} e^{-r/2a} \right]^2 \quad (7)$$

Then $B_{2s1}=0.24903\Delta$ (T), $B_{2s1-2}=-0.49807\Delta$ (T), $B_{2s3}=0.37356\Delta$ (T)

$$B_{2s} = B_{2s1} + B_{2s1-2} + B_{2s3} \\ = 0.12452\Delta(T) \quad (8)$$

It is interesting that B_{2s1-2} term is negative which will reduce the magnetic field of the hydrogen atom at 2s state. This term represents the movement of electron change from the "pure" electron spin to the orbital movement but compared to the "pure" electron spin and "pure" orbital movement of electron, this term makes counter contribution to the magnetic field of the hydrogen atom.

Conventionally, the transition of electron from 1s state to 2s state or vice versa is prohibited [29]. The probability for this transition is zero from the quantum mechanics calculation. However, the

experimental result does show the transition intensity from 1s to 2s or vice versa in spectrum is much weaker than the other transition but not zero. Till now, no reasonable explanation about this nonzero transition probability can be found in the literature and most of researchers select to ignore this "small" inconsistency between the theoretical prediction of quantum mechanics and experimental result.

Based on our result here, nonzero transition intensity in spectrum for the prohibited transition comes from the impure spin movement of electron in 2s state. It is the impurity caused by the radial orbital movement mixed in 2s state that makes the transition intensity from 1s to 2s (or vice versa) even weak but not zero.

From the data in Table 2, we noticed that the electron in 2s and 2p orbital makes the same contribution to the magnetic field of the hydrogen atom. We are surprised about this result because we all know the shapes of 2p orbital are totally different from that of 2s orbital, how they can keep the same contributions to the magnetic field of the hydrogen atom? After carefully analyzing, we found it is reasonable because topologically, as long as the electron moves around a fixed point (here it is the proton in hydrogen atom), the orbital movements are the same, which are irrelative to the orbital shapes [30]. That means topologically, 2s and 2p orbital are the same. That is the reason why they make the same contributions to the magnetic field of the hydrogen atom.

The data in Table 2 also show us that the electron in 3s, 3p and 3d orbital makes the same contributions to the magnetic field of the hydrogen atom as in 2s and 2p case. Here we should point out the fact that from 1s to 2s, 2p to 3s, 3p and 3d, their contributions to the magnetic field of the hydrogen atom are different. From the discussion in the paragraph 2 above, we already know that the contribution from the electron movement in the hydrogen atom to the magnetic field of the hydrogen atom is irrelevant to the shape of the electron movement in the hydrogen atom, then here it reveals that the contribution from the electron movement in the hydrogen atom to the magnetic field should be only energy dependent. That means the higher the eigen value of the electron in the hydrogen atom, the stronger the contribution to the magnetic field of the hydrogen atom. This point is easy to understand because the electron is closer to the proton in the hydrogen atom, it will have higher the eigen value; then the higher eigen value, the

electron in the hydrogen atom will move faster; the electron moves faster, it will make stronger contribution to the magnetic field of the hydrogen atom.

Our result here demonstrates that the magnetic field of the hydrogen atom comes from the electron movement around the proton in the hydrogen atom, not from the “intrinsic property” or “relativity effect” of electron. The contribution from the electron movement to the magnetic field of the hydrogen atom is not a constant as predicted in the traditional quantum mechanics (the traditional quantum mechanics tell us the magnetic momentum from the electron spin is $\pm \frac{1}{2} \hbar$, which is a constant) [31] but the energy dependent instead. This fact tells us again the magnetic field in the hydrogen atom comes from the movement of the electron around the proton in the hydrogen atom, not “intrinsic property” or “relativity effect” of the electron, therefore, we don't need to attach an extra term onto the wavefunction from the solution of Schrödinger's equation and these wrong concepts do should be discarded. Accordingly, the quantum mechanics should be rebuilt.

3. POTENTIAL APPLICATION REGARDING THE MAGNETISM FROM THE MOVEMENT OF THE ELECTRON IN ATOM

The solution of the Schrödinger's equation has found wide application in physics and chemistry but here we would like to mention two potential applications based on our calculation above.

a. Atomic and molecular magnetic spectroscopy

From the discussion above, we know that the electron in different orbital in atom or molecule makes different contribution to the magnetic field of the atom or molecule, therefore, the different atom or molecule will show different behaviors under the applied inhomogeneous magnetic field. Based on this result, we can setup the magnetic spectroscopy and the different atom or molecule will show the different style in its spectrum under the applied inhomogeneous magnetic field. Furthermore, we can use this kind of magnetic spectroscopy to follow the behavior of electron in chemical reaction, transportation of electron in conductor, etc, which offers us a tool to get insight into the detail mechanism of electron movement in these processes.

b. Separation of the atom or molecule from their mixtures

Our result here demonstrates that under the applied inhomogeneous magnetic field, the atom or molecule will show two states, that means the atom or molecule will move along two directions (see the detail in reference [24]. The angle between the two direction paths of atom or molecule movement depends on the atom or molecule and the strength of the applied inhomogeneous magnetic field. This offers us a method to separate the different atom or molecule from their mixtures. The precision of separation depends on the strength of the applied inhomogeneous magnetic field. The stronger the applied inhomogeneous magnetic fields, the higher the precision of the separation can be reached. This property of the atom or molecule revealed in our work has special important application in the high precision industry.

4. CONCLUSION

From our calculation and discussion above, we concluded that the magnetism from the movement of electron in hydrogen atom is eigenvalue dependent, not constant. The concept about the origin of magnetism from the “intrinsic property” or “relativity effect” of electron should be discarded. The extra term added onto the wavefunction to describe the electron spin is unnecessary. Furthermore, based on our result, the quantum mechanics should be rebuilt. Further work will be presented later.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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