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A Review of the Bohr's Model of Hydrogen Atom

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Author's contribution

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

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ABSTRACT

In this paper, the classical Bohr's model of the hydrogen atom has been revisited. Two values of fundamental physical properties of an electron in the hydrogen atom has been identified. These physical properties ($v_e = 174090.938ms^{-1}$ & $p_e = 1.585860888 \times 10^{-25} kgms^{-1}$) are constant in nature. The aim for the review was to contribute to the solution of disagreement between the Bohr's wavelength ($\lambda_o = 91.12nm$) and the Balmer's experimental observation ($\lambda_o = 91.18nm$) for the emission spectrum of hydrogen atom. There are two other constants $\delta = 7.199822 \times 10^{-10} eVm$ and $\xi = 1503796277m^{-1}$ that were identified in the Bohr's equation of the hydrogen atom.

The four fundamental physical constants are intrinsic properties of an electron and can be applied to multi-electron system. They can also be obtained from Schrodinger's equation for hydrogen atom at steady state. These constants may be subjected to scrutiny for their determination for better understanding. Also, since Bohr's model of hydrogen atom is based on classical mechanics, this paper has provided an alternate method of solving simple problems in atomic physics under Bohr's model to aid good mental picture of hydrogen atom to scientists.

Keywords: Bohr's model; hydrogen atom; constant velocity.

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1. INTRODUCTION

The application of Neil Bohr's theorem of hydrogen atom to the study of atomic structure in quantum physics is still relevant because it provides convenient mental picture to students despite its limitations [1,2,3]. His theory on hydrogen atom worth examining because it provides concrete transition from real classical world to the abstract world of quantum theories [4,1,5,6]. The theory based on basic newtonian physics principles was able to predict scientific formula for the approximate calculation of discrete spectrum of the hydrogen atom [2,5,7,3].

Bohr's prediction was close but not exact to the Balmer's experimental observation because it was assumed that the proton in the nucleus remains at rest while the electron orbits around it [4,5,7]; though in reality both particles rotate about their common centre of mass [4,7,3]. The centre of mass is shifted close to the massive proton [4,3]. However, proton is not entirely motionless [7,3]. Advanced studies and analysis account for the motion of the massive proton which slightly changes the energies of the electron at stationary states to one part in two thousand which is necessary to revise the error [7,3].

However, upon arithmetical arrangements of the physical parameters in Bohr's equation for the hydrogen atom at stationary states, it is obviously seen that the electron in the hydrogen atom exhibits another motion besides orbiting [8]. This motion actually has effect on the total energy of the electron and has caused significant error in the subsequent quantum models [9,10]. Based on the equations presented in this paper, the motion is an intrinsic property and its magnitude is constant at all levels of quantised energy states. As a result, it provides the electron a constant momentum at each energy level.

The effect of this motion on the energy states of an electron bound to the nucleus has not been considered on various quantum atomic models. Therefore, it is very important to further probe into studies and analyses of the energy states of an electron in the hydrogen atom. Also, this constant motion of an electron may influence the fundamental properties and other quantum parameters that describe the energy state of an electron in the hydrogen atom.

2. THEORIES

Bohr's equation for the hydrogen atom at the steady state is given by:

$$E_n = -\frac{me^4}{8\varepsilon_o^2 h^2 n^2} \tag{1}$$

Equation for the postulate on angular momentum:

$$mv_n r_n = \frac{nh}{2\pi} \tag{2}$$

Equation for Bohr's radius is given by:

$$r_n = \frac{\varepsilon_o n^2 h^2}{\pi m e^2} \tag{3}$$

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

$$E_n = -\frac{me^4}{8\varepsilon_o^2} \times \frac{\varepsilon_o}{\pi m e^2 r_n} = -\frac{e^2}{8\pi\varepsilon_o r_n} = -\frac{\delta}{r_n} \tag{5}$$

From (5), the energy of an electron bound to the nucleus in the hydrogen atom at the steady state is inversely proportional to its corresponding Bohr's radius.

$$\delta = 1.153538564 \times 10^{-28}\, Jm \tag{6}$$

$$\delta = 7.199822 \times 10^{-10}\, eVm \tag{7}$$

$$E_n = -\frac{\delta}{r_n} = -\frac{h}{h} \times \frac{\delta}{r_n} = -\frac{\delta}{h} \times \frac{h}{r_n} = -v_e \times \frac{h}{r_n} \tag{8}$$

$$v_e = \frac{\delta}{h} = \frac{1.153538564 \times 10^{-28}\, Jm}{6.62606896 \times 10^{-34}\, Js} \tag{9}$$

$$v_e = 174090.938 ms^{-1} \tag{10}$$

$$\Delta E = hf = v_e h\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \tag{11}$$

$$f = v_e\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \tag{12}$$

$$E_n = -\frac{v_e h}{r_n} \tag{13}$$

$$r_n = \frac{nh}{2\pi m v_n} \tag{14}$$

$$E_n = -v_e h \times \frac{2\pi m v_n}{nh} = -2\pi m v_e \left(\frac{v_n}{n}\right) \quad (15)$$

$$\Delta E = 2\pi m v_e \left(\frac{v_1}{n_1} - \frac{v_2}{n_2}\right) \quad (16)$$

$$f = \frac{m v_e}{\hbar}\left(\frac{v_1}{n_1} - \frac{v_2}{n_2}\right) \quad (17)$$

$$f = \xi\left(\frac{v_1}{n_1} - \frac{v_2}{n_2}\right) \quad (18)$$

$$\xi = 1503796277 m^{-1} \quad (19)$$

$$p_e = m v_e = 9.10938215\times10^{-31} kg \times 174090.9385 ms^{-1} \quad (20)$$

$$p_e = 1.585860888\times10^{-25} kgms^{-1} \quad (21)$$

$$2\pi m v_e = 9.964257829\times10^{-25} kgms^{-1} \quad (22)$$

Some velocities of an electron in various Bohr's orbits:

$$v_1 = 2187691.253 ms^{-1} \quad (23)$$

$$v_2 = 1093845.627 ms^{-1} \quad (24)$$

$$v_3 = 729230.419 ms^{-1} \quad (25)$$

$$v_4 = 546922.8135 ms^{-1} \quad (26)$$

Schrodinger's Steady State Equation for Hydrogen Atom:

$$E_n = -\frac{me^4}{32\pi^2\varepsilon_o^2\hbar^2}\left(\frac{1}{n^2}\right) = \frac{E_1}{n^2} = \frac{v_e h}{r_n} = 2\pi m v_e\left(\frac{v_n}{n}\right) \quad (27)$$

$$E_1 = -\frac{me^4}{32\pi^2\varepsilon_o^2\hbar^2} = -\frac{\hbar^2}{2ma_o^2} \quad (28)$$

Where:

m is the mass of an electron; e is the fundamental charge of an electron; h is the Planck's constant; n is the principal quantum number; ε_o is the permittivity of vacuum; a is the Bohr's radius; v_n is the orbital velocity corresponding to the principal quantum number concerned; v_e is the proposed classical spin velocity for the electron from Bohr's hydrogen model; f is the emitted/absorbed frequency due to electron quantum transition; ΔE is the energy emitted/absorbed due to electron quantum transition; E_n is the energy of an electron corresponding to the principal quantum number concerned; r_n is the radius corresponding to allowed orbit; p_e is the proposed classical constant momentum due to electron spin; and δ , ξ are physical constants deduced from the classical hydrogen atom of the Bohr's model.

3. DISCUSSION

Upon valid arithmetical arrangements of the equations (8), (12), (17) and (27); it is seen that electron in the hydrogen atom naturally exhibits another motion and momentum besides the orbital motion described in the theory. Actually, this motion may be spinning in nature [11,8,10] as suggested by Goudsmit and Uhlenbeck in a classical view. The motion is also observed in Schrodinger's equations for hydrogen atom at the steady state.

From the equations (11) & (16), change in energy state from an allowed orbit to another is not affected by the velocity, v_e of the motion. Also, equations (12) & (17) suggest that frequency of radiation emitted upon quantum transition is unaffected by the motion, v_e, of the electron. Likewise, the momentum is also observed to be constant in (15), (16) & (27). However, the orbital angular velocity, v_n changes in magnitude whenever principal quantum number, n is altered.

4. CONCLUSIONS

From Bohr's and Schrodinger's equation for an electron bound to the nucleus of the hydrogen atom at steady state, electron in the hydrogen atom describes a constant motion at $v_e = 174090.938 ms^{-1}$. Also, besides the angular momentum propounded by the Bohr's model, there exist another momentum exhibited by the electron at $p_e = 1.585860888 \times 10^{-25} kgms^{-1}$. This momentum may confirm the statement of both Dirac and Darwin who suggested that the momentum-energy of an electron is the sum of mechanical momentum-energy and the electromagnetic momentum-energy. However, unlike orbital motion and angular momentum that changes in magnitude at each energy level, these two properties remain constant irrespective of the energy level. Hence, they are intrinsic properties exhibited by the electron in the hydrogen atom. Although the motion was derived through classical approach, it may contribute to the reason why Sommerfield's formulae for energy level could not predict the Lamb effect or hyperfine structure. Also, the effect of this suggested rotational motion may basically account for the origin of magnetic moment exhibited by electrons that was suggested by Pauli.

In conclusion, the source of error to the inconsistency between Bohr's and Balmer's wavelength is not only due to the effect of the motion of proton on the energy state of the electron but the considerations for the motions of electron also. Moreover, this paper has provided an alternate classical approach and ideas in solving trivial problems under Bohr's model of hydrogen atom for better understanding.

5. RECOMMENDATIONS

There exist many advanced scientific models in quantum physics describing atomic nature and energy states of electrons but each has its own assumptions, complications and limitations. However, these atomic models basically left out considerations for such important physical constants identified in this study. Particularly, Schrodinger's quantum atomic model on the hydrogen atom at steady state failed to consider such physical properties that existed in Bohr's theory. The study recommends that current quantum atomic models and equations governing quantum physics should be revisited for better applications and understanding of the physical world.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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