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A Non-nuclear Model of the Hydrogen Atom

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Abstract

A non-nuclear model of the atom of hydrogen gas is devised consisting of N_h planar orbits each with two particles of the same mass *nm* and opposite charges, of magnitude equal to the electronic charge *e*, revolving in the nth orbit round a common centre. A particle revolves through angle ψ, in an unclosed elliptic orbit, at a distance *r* from the centre, as:

$$\frac{1}{r}=\frac{A}{n}\exp(-b\psi)\cos(\alpha\psi+\beta)+\frac{m\kappa}{nL^2}$$

where *A* and β are determined from the initial conditions, *b*, α, and κ are constants, *nL* is a constant angular momentum in the nth orbit and *m* is the electronic mass. The number *n* (1, 2, 3...N_h) leads to quantisation of the orbits. The decay factor, $exp(-b\psi)$, is the result of radiation as a particle revolves and settles in the nth stable orbit, a circle of radius $r_n = nL^2/m\kappa$ with speed $v_n = \kappa/nL$. Interactions between revolving particles, in each of the $\boldsymbol{N_h}$ orbits, give rise to radiation of discrete frequencies in accordance with the Balmer-Rydberg formula for the hydrogen spectra.

Keywords: Angular momentum, hydrogen atom, centre of revolution, radiation.

1 Introduction

The paper introduces a non-nuclear model of the hydrogen atom for the gas state. This model is different from the Rutherford's nuclear model [1] and also different from the nuclear model described by the author [2]. The non-nuclear model is stabilized and the Balmer-Rydberg formula [3], for discrete frequencies of emitted radiation, is derived, without recourse to Bohr's quantum mechanics [4].

The Balmer-Rydberg formula [3] gives the wave number of emitted radiation from the hydrogen atom as:

$$\frac{1}{\lambda_{nq}}=R\left(\frac{1}{n^2}-\frac{1}{q^2}\right)\textit{per metre} \tag{1}$$

where R is the Rydberg constant and *n* and *q* are integers greater than 0, with *q* greater than *n*. Niels Bohr [4] derived the formula as:

$$\nu_{nq}=\frac{1}{\lambda_{nq}}=\frac{me^4}{8c\varepsilon_o^2h^3}\left(\frac{1}{n^2}-\frac{1}{q^2}\right)\textit{per metre} \tag{2}$$

where m is the electronic mass, e the magnitude of the electronic charge, c is the speed of light in a vacuum, ε_o is the permittivity of a vacuum and h the Planck constant. The Rydberg constant R, is:

$$R = \frac{me^4}{8c\varepsilon_o^2 h^3} \ per\ metre \tag{3}$$

An alternative model of the hydrogen atom is introduced in this paper. The non-nuclear model, called *bipolar model*, is for the gas state of the hydrogen atom. The bipolar model consists of a number N_h of circular orbits in one plane. The nth stable circular orbit consists of a particle of charge $-e$ and mass nm at a distance $2nr_1$ from another particle of the same mass nm but charge $+e$ revolving with speed v_1/n and constant angular momentum nL, under mutual attraction. Here, n is an integer: $1, 2, 3...N_h$. The radius r_1, speed v_1 and angular momentum L are for the inner orbit, the first orbit with n = 1. The pair of oppositely charged particles makes up the two poles of a bipolar orbit.

In the stable state, a particle of mass nm, in the bipolar or non-nuclear model, revolves in the nth circular orbit. If a particle is disturbed from the nth stable circular orbit, it revolves as a radiator emitting a burst of radiation of increasing frequency and decreasing intensity as it spirals out towards the stable circular orbit. The frequencies of emitted radiation are very nearly equal to that of revolution in the nth circular orbit.

In the bipolar model, an excited hydrogen atom will consist of a number of radiators with the charged particles oscillating in (unclosed) coplanar elliptic orbits. In the following section, it is shown that interaction between a particle of the in the nth orbit and another in the qth orbit results in emission of radiation of discrete frequencies in accordance with the Balmer-Rydberg formula for the spectrum of the hydrogen atom in the gas state.

The derivation of Balmer-Rydberg formula, without recourse to Bohr's quantum theory, is the most remarkable result of this paper. It avoids the ad-hoc restrictions and removes the quantum jump of an electron as a necessary condition for emission of radiation from the hydrogen atom. It also relates the frequencies of radiation to the frequencies of circular revolutions of the electrons, something which the quantum theory failed to do.

2 Non-nuclear model of the hydrogen atom

The non-nuclear model of the hydrogen atom consists of a concentric arrangement of N_h coplanar orbits. The orbits are equally spaced, each with two particles of charges $-e$ and $+e$ and same mass nm revolving in the nth orbit round a centre of revolution, centre of mass of the particles.

2.1 Equation of the orbit of motion

The equation of the orbit of motion of a particle of mass nm revolving, in the nth orbit, at a point distance r from the centre, is derived by the author [5], as:

$$\frac{1}{r} = \frac{A}{n}\exp(-b\psi)\cos(\alpha\psi + \beta) + \frac{m\kappa}{nL^2} \tag{4}$$

where the amplitude A and phase angle β are determined from the initial conditions, b, α are constants, $\kappa = e^2/16\pi\varepsilon_o$ and nL is a constant angular momentum in the nth orbit..

The exponential decay factor $(-b\psi)$, in equation (4), is as a result of radiation of energy. The two charged particles will revolve, round their centre of mass, in an unclosed (aperiodic) elliptic orbit with many cycles of revolutions, radiating energy, before settling down into the nth stable orbit, a circle of radius $nL^2/m\kappa$.

2.2 Radiation from the non-nuclear model

The non-nuclear or bipolar model of the hydrogen atom consists of a concentric arrangement of N_h coplanar orbits. Each orbit has two particles revolving under mutual attraction, round a common centre of revolution. A particle revolves in a stable circular orbit of radius $r_n = nr_1 = nL^2/m\kappa$ with velocity $v_n = v_1/n = \kappa/nL$, where $\kappa = e^2/16\pi\varepsilon_o$ and $n = 1$ for the innermost orbit. Such a configuration of N_h orbits is shown in Figure 1. The non-nuclear (bipolar) model of the hydrogen atom, in contrast to the nuclear (unipolar) model, has no particle as the nucleus, but an empty centre of mass as the centre of revolution for all the particles in the N_h orbits.

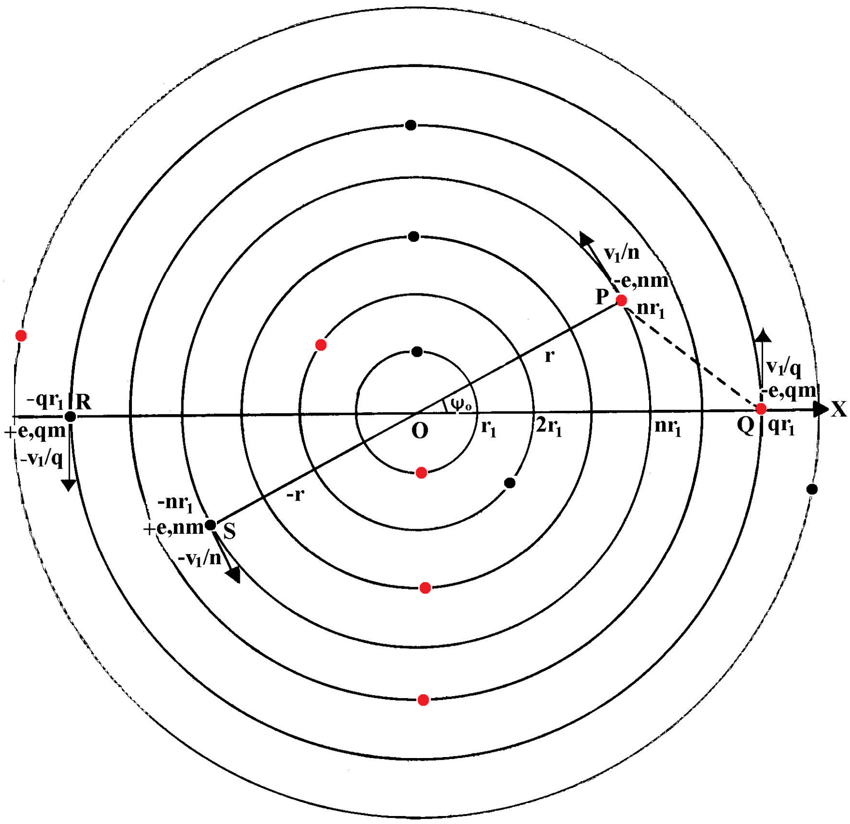

Figure.1.Non-nuclear model of the hydrogen atom, consisting of a number N_h of coplanar orbits each with two equal but oppositely charged particles revolving, anti clock-wise, in angle ψ, under mutual attraction. Each of the two particles in the nth orbit has mass nm, one carries charge $-e$ and the other $+e$, n being an integer 1 - N_h, m is the electronic mass and $-e$ the electronic charge. The nth pair of particles revolves in a circular orbit of radius nr_1 with velocity v_1/n and constant angular momentum $nmv_1r_1 = nL$

The frequency of revolution of a particle moving with constant speed v_n in the nth stable orbit, a circle of radius r_n, is:

$$f_n = \frac{v_n}{2\pi r_n} = \frac{me^4}{16\pi n\varepsilon_o L}\frac{1}{2\pi\left(16\pi n\varepsilon_o L^2\right)} = \frac{me^4}{2\pi\left(16\pi\varepsilon_o\right)^2 L^3}\frac{1}{n^2} \tag{5}$$

Putting $L = h/4\pi$ gives equation (5) as:

$$f_n = \frac{me^4}{2\pi\left(16\pi\varepsilon_o\right)^2 L^3}\frac{1}{n^2} = \frac{me^4}{8\varepsilon_o{}^2 h^3}\frac{1}{n^2} = \frac{cR}{n^2} \tag{6}$$

where the Rydberg constant $R = me^4/8c\varepsilon_o{}^2h^3$, has the value *(1.097* $\times$ *10*^{7} *per metre)* as obtained by Bohr [4] and confirmed by observation. The Planck constant h appears here in a manner reminiscent of Bohr's first postulate which makes $nL = nh/2\pi$ as the angular momentum in the nth orbit, in contrast to the angular momentum, $nL = nh/4\pi$, as advanced here in order to arrive at equation (6).

If a particle, revolving in the nth orbit with frequency f_n, is dislodged from the stable circular orbit, it revolves as a radiator in an unclosed (aperiodic) elliptic orbit. It emits a burst of radiation of frequencies very nearly equal to f_n that of revolution given by equation (6), before reverting back into the nth stable circular orbit.

2.3 The Balmer-Rydberg formula

We shall now follow the motion of particles in two bipolar orbits with the particles at positions P and Q of radii nr_1 and qr_1 respectively, revolving in anticlockwise sense round the centre O as in Figure 1. The frequencies of revolution at P and Q are given by equation (6) for the respective orbital numbers n and q.

In Figure 1 let the particles at positions P and Q both have negative charges at the initial stage. The relative positions of the points *S, R, O, P* and Q are as shown, with ***OP*** and ***OQ*** at an angular displacement ψ_o at the initial stage, time $t = 0$. In time t let the line ***OP*** move to $\boldsymbol{OP_t}$ through an angle ψ_n, and let the line ***OQ*** move to $\boldsymbol{OQ_t}$ through an angle ψ_q. The difference in angular displacement, the instantaneous angle $\boldsymbol{P_tOQ_t}$, is:

$$\psi_t = \psi_o + \psi_n - \psi_q$$

The angular frequency of oscillation of the particles at P and Q, is:

$$\frac{d\psi_t}{dt} = \frac{d\psi_n}{dt} - \frac{d\psi_q}{dt} = \omega_n - \omega_q = 2\pi f_n - 2\pi f_q = 2\pi f_{nq} \tag{7}$$

Combining equation (7) above with equation (6) where $f_n = cR/n^2$ and $f_q = cR/q^2$, gives:

$$f_{nq} = cR\left(\frac{1}{n^2} - \frac{1}{q^2}\right) \tag{8}$$

The four particles in two bipolar radiators, of the hydrogen atom, behave like oscillating pairs, emitting radiation in a narrow band of frequencies, with wave numbers ν_{nq} as:

$$v_{nq} = \frac{f_{nq}}{c} = R\left(\frac{1}{n^2} - \frac{1}{q^2}\right) \tag{9}$$

The atomic particles revolve in their respective orbits as radiators. Interactions between the $2N_h$ particles, in all the N_h number of orbits, result in the emission of radiation of discrete frequencies and wave numbers given by equations (8) and (9) respectively. Also, the atom can absorb radiation of the same frequencies as it emits. The arrangement of the particles, their revolutions and interactions between them, giving rise to emission or absorption of radiation, determines the physical and chemical properties and thermal condition of the atom,

Equation (9), identical to the Balmer-Rydberg formula (equation 1), is the result of interactions between excited charged particles as they revolve in their different unstable orbits. This is what this paper has set out to derive without recourse to quantum mechanics. In the process, the frequencies of emitted radiation are directly related to the frequencies of revolutions of the charged particles; something which quantum mechanics failed to do.

2.4 Number of orbits in the non-nuclear model

The hydrogen atom is found to be about 1836 times the mass m of the electron. The total number N_h of orbits, each containing two particles either of mass nm, is obtained from the sum of the natural numbers: $n = 1, 2, 3, \ldots N_h$. Twice this sum, which carries the mass of the atom, gives $N_h(N_h + 1)m = 1836m$. This gives $N_h = 42.35$. N_h should be an integer.

3 Non-Nuclear model versus nuclear model

The non-nuclear model of the hydrogen atom has no nucleus but an empty centre round which particles revolve in N_h coplanar orbits. Two positive and negative particles ($+e$ and $-e$), each bearing a multiple nm of the electronic mass m, revolve in the nth orbit, n being an integer: $1, 2, 3 \ldots N_h$. The total mass of particles in the N_h orbits, with two particles in each orbit, is $N_h(N_h + 1)m$. The positive and negative charges, in an atom, cancel out exactly.

The new nuclear model has a nucleus of charge $+N_he$ and N_h coplanar orbits in each of which particles of charge $-e$ and mass nm revolve. The total charge of the negative particles is $-N_he$, equal and opposite of the charge on the nucleus. The total mass of the N_h revolving particles is $\frac{1}{2}N_h(N_h + 1)m$, same as the mass of the nucleus. Thus the bipolar model and unipolar or nuclear model of the hydrogen atom have the same number of orbits N_h and the same mass, equal to $N_h(N_h + 1)m$. The question now is: "What is the significance of these two different models of the hydrogen atom?"

It is suggested here that the non-nuclear (bipolar) model is what obtains with the gas phase of hydrogen while the new nuclear model exists with respect to the liquid and solid phases, depending on the ambient temperature. Let us now determine the relationship between the constant S as obtained by the author [2] for the nuclear model and the Rydberg constant R obtained from equation (6), for the non-nuclear model. The expression obtained, equal to the ratio of frequency g_n in the nuclear model and the frequency f_n in the non-nuclear nuclear model, is:

$$\frac{S}{R} = \frac{g_n}{f_n} = 16N_h^2 \tag{10}$$

The ratio s_n of radius of revolution in the nth orbit of the nuclear model and the radius r_n of the non-nuclear model, is obtained as:

$$\frac{s_n}{r_n} = \frac{1}{4N_h} \qquad (11)$$

The ratio u_n of speed of revolution in the nth orbit of the nuclear model and the speed v_n in the non-nuclear obtained, is obtained as:

$$\frac{u_n}{v_n} = 4N_h \qquad (12)$$

It is assumed that the constant angular momentum nL, with respect to the nth stable orbit, is the same for the nuclear and non-nuclear models of the hydrogen atom.

4 Conclusion

Expressions for the Balmer-Rydberg formula and the Rydberg constant (equations 1 and 2), for the non-nuclear or bipolar model of the hydrogen atom, are derived without recourse to Bohr's second postulate but with a modification of the first postulate. The modification is to the effect that *the magnitude of the angular momentum of a particle of mass nm, revolving in the nth circular orbit, is equal to* $nL = nh/4\pi$, where $h = 6.626 \times 10^{-34}$ J-sec. Quantisation of angular momentum (nL) and radius of revolution $(nL^2/m\kappa)$ and inverse quantisation of velocity (κ/nL) appear naturally as a consequence of discrete masses (nm), being multiples of the electronic mass m, with n as the orbital number, an integer greater than 0.

The angular momentum of a particle in the first orbit of the bipolar model, is $L = h/4\pi$. This is a fundamental quantity of value equal to $L = 5.273 \times 10^{-35}$ *J-sec*. It defines the Planck constant h in terms of angular momentum rather than "unit of action". Even though the Planck constant is featuring prominently, Bohr's quantum mechanics is not necessary in describing the discrete frequencies of radiation from the hydrogen atom.

The radius of the first orbit $(n = 1)$ of the non-nuclear model of the hydrogen atom is obtained as $r_1 = \varepsilon_o h^2/\pi m e^2 = 5.292 \times 10^{-7}$ *m*. This is the same as the **first Bohr radius** [4] obtained, through quantum mechanics, for the nuclear model of the hydrogen atom. The speed of revolution in the first orbit of the non-nuclear model is obtained as $v_1 = e^2/4\varepsilon_o h = 1.094 \times 10^6$ *m/s*. This is different from the speed of revolution in the **first Bohr orbit** of the nuclear model, which is $u_1 = N_h e^2/\varepsilon_o h$ *m/s*. A knowledge of the charge $+N_h e$ in the nucleus, as may be obtained from experiment, is required in order to determine the radius $s_1 = \varepsilon_o h^2/4N_h\pi m e^2$ and speed u_1 of revolution (equations 11 and 12) in the new nuclear model.

The Rutherford-Bohr nuclear model of the hydrogen atom does not distinguish between the models in the gaseous state and in the liquid or solid state. The new nuclear model described by the author [2] is for the liquid or sold state and this paper gives the non-nuclear model for the gaseous state. The Balmer-Rydberg formula, which explains the frequencies of radiation in the hydrogen atom spectrum [3], should be for the gaseous state.

This paper gives two sources of radiation from the hydrogen atom. The first is from interaction between the two radiators in the nth orbit. A particle revolves in an unclosed (aperiodic) elliptic orbit emitting radiation of increasing frequencies and decreasing amplitude before settling in the nth stable circular orbit. Thus radiation from a revolving particle is a narrow band of frequencies very nearly equal to the frequency of revolution f_n given by equation (6). The second source of radiation is from interaction between particles revolving in the nth and qth orbits, resulting in radiation of frequency f_{nq} given by equation (8).

The series limit of the frequencies given by equation (8), with $q \rightarrow \infty$, is the same as the frequency given by equation (6). This may explain why the intensity of the series limit is not zero. For the Balmer series [5, 6, 7] the frequency limit, $f_2 = cR/4 = 8.227 \times 10^5\ GHz$, in the violet region (not visible), is present and measurable.

The nth orbit of the hydrogen atom, as well as the atom itself, could be considered as an "intelligent" configuration. Each orbit and the atom as a whole, if disturbed, "remembers" its previous condition or situation and returns to it, with an exhibition of energy. So, hydrogen atoms could combine and produce a manifestation of rudimentary consciousness.

5 References

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