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Nuclear and Non-nuclear Models of Atoms of Elements

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Abstract

An electron of charge *-e* or positron of charge *+e*, mass *m*, is a spherical shell of radius *a* and energy $e^2/8\pi\varepsilon_o a$, where ε_o is electric permittivity. An electron and positron at centres *2r* apart, revolving with speed *v* in a circular orbit, form a positronium of mass *2m* and potential energy $-e^2/8\pi\varepsilon_o r$, with energy radiation as $e^2/8\pi\varepsilon_o r$. The electron, positron and positronium are basic blocks of atoms. Rutherford's nuclear model of hydrogen atom, with an electron revolving round a positive nucleus, holds and is extended to other atoms. A Particle of mass *nm* revolves in the nth orbit of radius nr_1, where *n = 1, 2, 3…N*, for *N* orbits. Two models of hydrogen protium, atomic number *Z = 1*, are described. A nuclear model, for solid or liquid state, with particles each of charge *-e*, mass *nm*, total charge *-Ne* and total mass as arithmetic sum *½mN(N+1)*, revolving in *N* orbits under attraction of nucleus of charge *+Ne* and mass *½mN(N+1)*. A non-nuclear model, for gaseous state, has two particles of charges *-e* and *+e*, each of mass *nm*, total mass *mN(N+1)*, revolving in *N* orbits, under mutual attractions. The models emit radiation of discrete Balmer frequencies. Atomic temperature is ascribed to Lorentz forces on revolving charged particles cutting across magnetic fields of rotating nuclei or spinning charged particles, thereby decreasing force of attraction and potential energy, for heat radiation. Other atoms are with *Z* negative particles in each of *N* orbits and a nucleus of charge *+ZN*, or with *Z* positive and *Z* negative particles, under mutual attractions, for non-nuclear model. The nucleus of other elements has *ZN* positrons and *½ZN(N – 1)* positroniums, confined as rotating ring at the nucleus, by Lorentz forces due to magnetic fields of *ZN* revolving negative particles. At a pressure and boiling-point temperature, a nucleus breaks out to non-nuclear model.

Keywords: Atom, Electron, Energy, Field, Force, Heat, Lorentz Force, Mass, Orbit, Positron, Radiation, Unitron.

1. Introduction

All electrical phenomena are manifestations of electric charge and electric field, stationary and/or in motion. In this paper, magnitudes of scalar quantities, like electric charge *Q* and mass *m*, are written in *italicized type*, and vector qualities, which have magnitude and direction, like electric field **E** and velocity **v**, of magnitude (speed) *v*, are put in **bold-face type**. A unit vector, in the **v**-direction, is **û** = **v**/*v*. Familiarity with vector algebra, electricity and magnetism, differential and integral calculus, is assumed.

The existence of an indivisible quantity of electric charge was conceived by the British natural philosopher, Richard Laming, in 1838 [1]. The Irish physicist, George Stoney [2], named this indivisible charge "electron", in 1891. A team of British scientists, led by Sir J.J. Thompson [3, 4], identified the electron as a mobile negatively charged particle, in 1897. The electron is the most known entity in nature.

The story of the electron was closely associated with experiments on cathode rays. In the 1870s the English chemist and physicist, Sir William Crooks [5], had developed the cathode ray tube. He and others used it to show that cathode rays, emitted by a heated metal plate kept at a negative potential, were a stream of fast-moving negatively charged particles.

In 1896 the French physicist, Henri Becquerel [6], discovered radioactivity while studying naturally fluorescent minerals. This led the great New Zealand physicist, Sir Ernest Rutherford [7 - 10], to the discovery of alpha and beta particles and gamma rays emitted by radioactive metals. In 1900 Becquerel showed that beta rays were streams of negatively charged particles, the same as cathode rays. An alpha particle was identified by Rutherford as a positively charged particle, called proton, having the mass of a helium atom. Gamma rays (shorter than the familiar X-rays) are highly penetrating electromagnetic radiation with wavelength of 10^{-11} *to* 10^{-13} *m*.

The electronic charge was measured, in a meticulous experiment, by the American physicists, Robert Millikan [11] and Harvey Fletcher, in their oil-drop experiment of 1909. The negative electronic charge was found to be $e = -1.602\times10^{-19}$ *C* with a mass $m = 9.119\times10^{-19}$ *kg*, a constant independent of speed. The electron is the smallest, the lightest, most measured and best-known particle in nature.

At the beginning of the 20th century, it was found that fast-moving charged particles caused a condensation of saturated water vapor along its track. In 1911, Charles Wilson [12] used this finding to devise his cloud chamber. He used it to photograph the tracks of charged particles such as fast-moving electrons. This led to the discovery of fast-moving positrons, the antiparticles to the electrons.

The belief now is that an unstable atomic nucleus having too many protons relative to the number of neutrons, decays to stable form by converting a proton to a neutral particle called neutron. In the process a positron is ejected to conserve electric charge. It is believed that a positron annihilates with an electron, releasing two high-energy photons, in different directions, as gamma rays.

A positron, the antiparticle to the electron, has the same mass but a positive charge $+e$. The existence of a positron was theoretically predicted by Paul Dirac in 1913 [13], which he called "antielectron". The first evidence of existence of positron was in an experiment at California Institute of Technology, by Carl Anderson [14] under the supervision of Robert Millikan, in 1932. Anderson encountered strange particle tracks in his cloud chamber photographs, which he correctly interpreted as having been made by a positron, a particle having the same mass but opposite charge as the electron. A pulsed beam of positrons has been produced in the laboratory, but it had to be prevented from contact with any material other than the targeted cathode. Positrons completely vanish on contact with matter.

A positronium is a combination of an electron and a positron revolving diametrically in the same orbit round their common centre of mass. Classically, such a formation is supposed to be unstable, as the particles should run into one another and annihilate, with emission of gamma rays. In the same manner that the Rutherford's nuclear model of the hydrogen atom was supposed to be unstable, until it was brilliantly fixed by Niels Bohr [15].

In 1904 J.J. Thompson proposed the "plum pudding" model of the atom, soon after his discovery of the electron. In the Thompson's model, the atoms of the elements consisted of negatively charged corpuscles, called electrons, studded in a sphere of uniform positive electrification, like the raisins in a pudding – a tasty English dessert. The negative charges were balanced by the positive sphere to form the neutral atom as a stable entity.

A landmark series of experiments, Geiger-Marsden experiments or Rutherford gold foil experiments, on the scattering of alpha particles shot through a thin gold foil, were conducted between the years 1904 and 1909 [7 - 10]. Based on these experiments, Rutherford, in 1911, proposed a nuclear theory of the hydrogen atom, which superseded Thompson's model. Rutherford devised a model consisting of a heavy positively charged central nucleus round which a cloud of negatively charged electrons revolves in circular orbits. The hydrogen atom is the simplest, consisting of a single electron of charge $-e$ and mass m revolving in a circular orbit round a much heavier nucleus of charge $+e$. This model has sufficed since, although with some difficulties regarding its stability and mode of emission of radiation. The purpose of this paper is to extend Rutherford's nuclear model of hydrogen and other atoms of elements, with a view to modifying it, and/or eliminating some of its deficiencies and to deducing some incidental properties of its structure. In the process two models of the atom are identified. A nuclear model for the solid or liquid state and a non-nuclear model for the gaseous state, with discrete frequencies of radiation.

According to Abraham-Lorentz formula of classical electrodynamics [16], where radiation reaction force, due to a charged particle moving in an electric field, is proportional to the rate of change of acceleration, and Lamor formula where radiation power is proportional to the square of acceleration, the electron of the Rutherford's model, in being accelerated towards the positively charged nucleus of the atom, by the centripetal force, should:

(i) Emit radiation of continuous frequency range at power proportional to square of acceleration.

(ii) Lose potential energy and gain kinetic energy as it spirals into the nucleus, in atomic collapse.

The second prediction is contradicted by observation as atoms are the most stable objects known in nature. The first effect is contradicted by experiments as a detailed study of the radiation from hydrogen gas, undertaken by J. J. Balmer as early as 1885, as described by Francis Bitter [17], showed that the emitted radiation had discrete frequencies. The spectral lines in the Balmer series of the hydrogen spectrum, as generalized by Janne R. Rydberg, satisfy the Balmer-Rydberg formula:

$$\nu_{2q} = \frac{1}{\lambda_{2q}} = R\left(\frac{1}{2^2} - \frac{1}{q^2}\right) \tag{1}$$

where λ_{2q} is the wavelength, ν_{2q} is the wave number, R is the Rydberg constant and q an integer greater than *2*. The first four visible lines of the Balmer Series, with $q = 3, 4, 5, 6$ are *red*, *green*, *blue* and *violet* respectively. The series limit $(q \rightarrow \infty)$, in the ultra-violet (not visible) region of the spectrum, is $\nu_2 = R/4$.

Niels Bohr [15], in a fantastically brilliant display of original thinking, rescued the atom from radiating and collapsing by invoking the quantum theory and creating two, somewhat ad-hoc, postulates that prevented the atom from radiating energy. Bohr's postulates are:

(i) In those orbits where the angular momentum is $nh/2\pi$, n being an integer and h the Planck constant, the energy of the electron is constant.

(ii) The electron can pass from an orbit of energy E_q to an inner orbit of energy E_n in a quantum jump, energy difference is released as radiation of frequency f_{nq}, with energy as $E_q - E_n = hf_{nq}$

The first postulate quantized the angular momentum with respect to (quantum) number n. With these postulates Bohr was able to derive a formula for the wave numbers of the lines of the spectrum of the hydrogen atom, in agreement with observation [18]. Bohr's success gave the greatest impetus to quantum mechanics. He derived the same mathematical form as obtained by Balmer and generalized by J.R. Rydberg in 1889. Bohr's model gives wave number:

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

$$\frac{1}{\lambda_{nq}} = R\left(\frac{1}{n^2} - \frac{1}{q^2}\right) per\ meter \tag{3}$$

where n and q are integers, with $q > n$, c is the speed of light in a vacuum, ε_o is the permittivity of a vacuum and h is Planck constant. Equation (3) is Balmer-Rydberg formula giving Rydberg constant R as:

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

Substituting the values of quantities in equation (4), $R = 1.097 \times 10^7/m$, in agreement with observation.

In equation (3), if $n = 1$ we have the Lyman series, in the far ultra-violet region of the spectrum [18]. R is the spectral limit for the Lyman series. For $n = 2$, we have the Balmer (red to violet lines) series and where $n = 3$ we get the Paschen series in the near infra-red region. In a series the lines crowd and their intensities should decrease to zero as the series limit is approached. Other series, in the infrared region, are obtained for $n = 4, 5, 6\ldots..N$, down to the microwave radiation. Note that quantum number n, in equation 3, is same as number n for an orbit of revolution round the nucleus of an atom, as in Figure 4.

The fact that a purely chanced agreement between observation and the physical quantities in equation (4) is highly improbable, lends some plausibility to Bohr's theory of the hydrogen atom. This theory gave great impetus to quantum mechanics and was recognized as a remarkable triumph of human intellect. However, a "quantum jump" in zero time and absence of a direct link between the frequency of the emitted radiation and the frequency of revolution of the electron, in its orbit, leaves a question mark on Bohr's epochal quantum theory of the hydrogen atom. Subsequently, Bohr's quantum theory was modified, notably by Sommerfeld [19], for elliptic orbits and for more complex atoms.

This paper depends on the inherent stability of circular revolution of charged particles round a central force of attraction, with no change in potential or kinetic energy. It also hinges on circular motion of oppositely charged particles, under mutual attraction. Radiation occurs if a charged particle is dislodged from a circular orbit. It then revolves in unclosed elliptic paths, with emission of radiation, at the frequency of revolution, with fine structure, before reverting to a stable circular orbit.

1.1 Two Models of the Hydrogen Atom

This paper introduces two models of the hydrogen protium atom, a nuclear model for the solid or liquid state of hydrogen and a non-nuclear model for the gaseous state, based on revolution of charged particles round a center [20]. The nuclear model here is different from Rutherford's model. Instead of one orbiting electron, of mass m, and charge $-e$, the proposed nuclear model has one negatively charged particle of mass nm, revolving in the nth orbit of N regular concentric coplanar orbits around the positive nucleus of mass M. The sum $-Ne$ of negative charges, revolving in N orbits and total mass of the orbiting particles, are respectively equal to sum of positive charges $+Ne$ and mass M of the nucleus.

1.2 Mass-energy Equivalence Law

The author [21] showed that the mass-energy equivalence law, for a particle of mass m, should be:

$$E = \frac{m}{2\mu_o \varepsilon_o} = \frac{1}{2}mc^2 \tag{5}$$

where m is a constant equal to the rest mass m_o, μ_o is the magnetic permeability and ε_o the electric permittivity of electric field occupying a vacuum and c is the speed of light in space, a vacuum. Equation (5) is in contrast with the relativistic equation: $E = mc^2$. Two derivations of equation (5) are given [21].

2. Combination of a Positron and an Electron

If a positron of charge $+e$ or electron of charge $-e$ is to assume a configuration, it is likely to be an impenetrable spherical shell or hollow sphere of radius a as the smallest length in nature. Such a figure has electrostatic field $\mathbf{E}_o$ in space and intrinsic energy E_n given by classical formula, as volume integral:

$$E_n = \frac{\varepsilon_o}{2}\int_V E_o^2(dV) = \frac{\varepsilon_o}{2}\int_a^\infty \left(\frac{e}{4\pi\varepsilon_o r^2}\right)^2 \left(4\pi r^2\right)(dr) = \frac{e^2}{8\pi\varepsilon_o a} \tag{6}$$

The intrinsic energy or electrostatic energy E_n, in equation (6), is also obtained by considering the charge e as built up from zero, by infinitesimal amounts, in its potential, $e/4\pi\varepsilon_o a$, at constant radius a.

In view of equation (5), equation (6) gives mass of the positron or electron is a constant. as:

$$m = \frac{\mu_o e^2}{4\pi a} \tag{7}$$

Figure 1 shows a positron of charge $+e$ and mass m and electron of charge $-e$ and mass m revolving with speed v in a closed circular orbit round a center of mass, to form a stable positronium. The structure is stable in circular motion where there is no change in potential energy or kinetic energy.

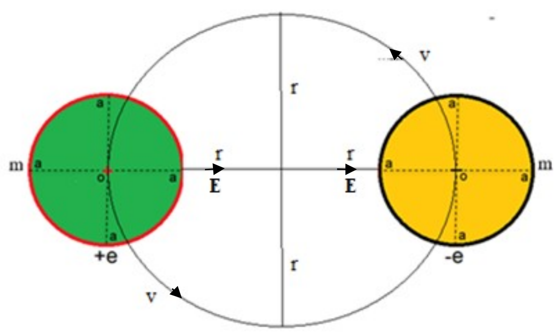

Figure 1: A positron of charge $+e$ and electron of charge $-e$, each of mass m, with electric field $\mathbf{E}$, revolving at speed v and kinetic energy $\frac{1}{2}mv^2$, under attraction, round center of a circle of radius r, forms a positronium with potential energy $-e^2/8\pi\varepsilon_o r$.

For revolution in unclosed elliptic paths there is radiation, at the frequency of revolution, before settling into a circular orbit of radius r. Circular revolution of a charged particle round a central force of attraction, is without radiation. Radiation comes if a revolving particle is dislodged from a circular orbit.

Both the revolving charges $+e$ and $-e$, in Figure 1, may spin or rotate in opposite directions to create a magnetic field perpendicular to the orbital plane. Let the charge e, with its electric field **E**, spin at angular frequency **ω**, with axis perpendicular to the orbital plane. Magnetic field intensity **H** created by charge e with electric field **E**, in the plane of the orbit of radius r, with velocity as vector product $\mathbf{v} = 2\boldsymbol{\omega}\times\mathbf{r}$, at the location of the other charge $-e$, distance $2r$ away, is given by another vector product:

$$\mathbf{H} = 2\varepsilon_o(\boldsymbol{\omega}\times\mathbf{r})\times\mathbf{E} = -2r\varepsilon_o E\boldsymbol{\omega} \tag{8}$$

where ε_o is the permittivity of electric field in a vacuum and **ω** is perpendicular **E**. Lorentz force **F** on particle of charge $-e$ and mass m moving in a circular orbit with speed v, through magnetic field **H**, is:

$$\mathbf{F} = -e\mathbf{E} - e\mu_o(\mathbf{v}\times\mathbf{H}) = -e\mathbf{E} + 2reE\mu_o\varepsilon_o(\mathbf{v}\times\boldsymbol{\omega}) = -e\mathbf{E} + 2re\mu_o\varepsilon_o(v\omega)\mathbf{E} = -m(v^2/r)\hat{\mathbf{u}} \tag{9}$$

where μ_o is the permeability of electric field, $(\mathbf{v}\times\boldsymbol{\omega})$ and unit vector $\hat{\mathbf{u}}$ are in the **E**-direction.

In equation (9), the electrostatic force of attraction between the charges e and $-e$ is reduced by $2re\mu_o\varepsilon_o(v\omega)\mathbf{E}$, thereby increasing their radius of revolution r and reducing the potential energy of the charge $-e$. Similarly, motion of the charge e in the magnetic field created by spin of the charge $-e$, causes increase in radius of revolution and decrease in its potential energy. The spinning of electric charges in an atomic particle is manifested as decrease in force of attraction, increase of separation of the revolving charges, decrease of potential energy for heat generation and rise of temperature in the gaseous state. This leads to gas expansion, or even gas explosion.

Figure 2 shows a positron of charge $+e$, mass m and intrinsic energy $E_n = e^2/8\pi\varepsilon_o a$, adjacent to an electron of charge $-e$, mass m and intrinsic energy E_n, at centers $2a$ apart. The particles unite, without annihilation, to form a positronium as a dipole, here called "unitron", of mass $2m$, intrinsic energy $2E_n$ and potential energy $-e^2/8\pi\varepsilon_o a$, with radiation of energy equal to $e^2/8\pi\varepsilon_o$a.

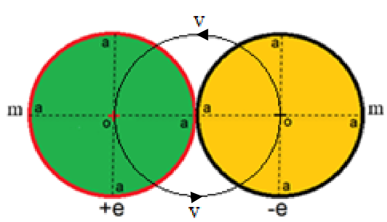

Figure 2: Positron of charge $+e$, mass m and electron of charge $-e$, mass m, centers $2a$ apart, forming a dipole, called "unitron", of mass $2m$, potential energy $-e^2/8\pi\varepsilon_o a$, in circular revolution of radius a, at speed v round center of mass.

In Figure 2, the positron and electron unite, without annihilation, with centers $2a$ apart, to form a neutral particle, special positronium called "unitron", of intrinsic energy $2E_n = e^2/4\pi\varepsilon_o a$, potential energy $-e^2/8\pi\varepsilon_o a$ and total energy $e^2/8\pi\varepsilon_o a = E_n = ½mc^2$. It is reasonable to assume that the "unitron" is a neutral particle of equivalent mass equal to the electronic mass $m = 2E_n/c^2$. It makes possible for n "unitrons" of mass nm to combine with a positron of charge $+e$ and mass m or an electron of charge $-e$ and mass m to create a new and neutral atomic particle of mass nm, where integer $n = 1, 2, 3.....N$, with N as the total number of orbits. For a positronium (Figure 1) or a "unitron" (Figure 2), the number of orbits is $N = 1$.

3. Nuclear Model of the Hydrogen Atom

The proposed nuclear model of the hydrogen atom consists of a concentric arrangement of N coplanar orbits. The orbits are equally spaced, each with a particle of charge $–e$, mass nm, of total mass as arithmetic sum $\frac{1}{2}N(N+1)m$, revolving in the nth circular orbit round a nucleus of mass $\frac{1}{2}N(N+1)m$ and positive charge $+Ne$. The nucleus contains N positrons and $\frac{1}{2}N(N-1)$ "unitrons", confined at the common centre, as the nucleus. The nucleus may rotate for radial electric field to create a magnetic field.

The equation of motion of a particle of mass nm revolving, in the nth orbit, with constant angular momentum nL, at a distance r from the nucleus, is derived as [20]:

$$\frac{1}{r}=\frac{A}{n}\exp(-q\psi)\cos(\alpha\psi+\beta)+\frac{m\chi}{nL^2}=\frac{A}{n}\exp(-q\psi)\cos(\alpha\psi+\beta)+\frac{B}{n} \tag{8}$$

where the amplitude of the excitement A and phase angle β are determined from the initial conditions and q *(exponential decay factor)*, α *(rotation factor)* and $\chi = Ne^2/4\pi\varepsilon_o$ are constants with nL as a constant angular momentum in the nth orbit, where $n = 1, 2, 3.....N,$ with N as the number of coplanar orbits.

The exponential decay factor $(-q\psi)$, in equation (8), is a result of radiation of energy. An excited negatively charged particle will revolve, round the positively charged nucleus, in an unclosed (aperiodic) elliptic orbit with some cycles of revolutions, radiating energy at the frequency of revolution, before settling into a stable circle of radius $nL^2/m\chi$, $= n/B$, where $1/B$ is equal to half of the latus rectum of the initial ellipse. The initial or free ellipse is the orbit of motion if the exponential decay factor $q = 0$.

3.1 Initial elliptic orbit and final stable circular orbit of nuclear model

The initial orbit of revolution of an excited electron is an ellipse with foci at F_1 and F_2 shown as WXYZ in Figure 2. As a result of radiation, the particle revolves in an unclosed orbit, in many cycles of revolution in angular displacement ψ, of increasing radius and decreasing speed, before settling in the stable orbit, circle CDEF of center F_1 and radius $n/B = nL^2/m\chi$ (latus rectum of free ellipse in Figure 3).

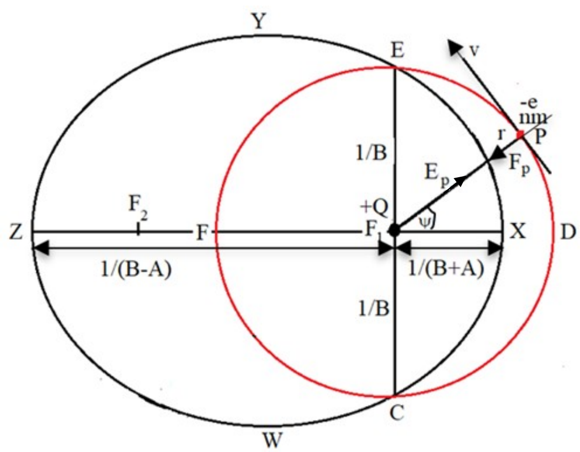

Figure 3: Free (Initial) ellipse WXYZ and stable circular orbit of revolution CDEF, of diameter as latus rectum EC, in a nuclear model with particle of charge $-e$ and mass nm at P revolving in the nth orbit at speed v, with angular displacement ψ and constant angular momentum $mnvr = nL$, under the attraction of field $\mathbf{E}_p$ due to nucleus of charge $+Q$ at the focus F_1.

Figure 3 shows the free ellipse WXYZ of focuses F_1 and F_2 with charge $+Q$ as nucleus. Here, the *exponential decay factor* $q = 0$, *rotation factor* $\boldsymbol{\alpha} = 1$ and *phase angle* $\beta = 0$. The length ZX is the *major axis* and EC the *latus rectum* as diameter of the final stable circular orbit CDEF.

Few circular stable orbits, n = 7, are depicted in Figure 4. A negatively charged particle revolves in the nth stable circle of radius $r_n = nr_1$ with speed $v_n = v_1/n$ where $n = 1$ for the first orbit. Frequency f_n

of revolution of a particle in the nth stable orbit, at speed v_n, in a circle of radius r_n, for nuclear model with a nucleus of charge $+Ne$ and N coplanar obits, is:

$$f_n = \frac{v_n}{2\pi r_n} = \frac{1}{2\pi}\frac{\chi}{nL}\frac{m\chi}{nL^2} = \frac{m\chi^2}{2\pi n^2 L^3} = \frac{mN^2e^4}{2\pi(4\pi\varepsilon_o)^2 L^3}\frac{1}{n^2} = \frac{cS}{n^2} \tag{9}$$

$$S = \frac{mN^2e^4}{2\pi c\left(4\pi\varepsilon_o\right)^2 L^3} \tag{10}$$

where S is a constant. If an electron is disturbed or dislodged from the stable circular orbit, it revolves in unclosed elliptic paths, emitting a burst of radiation in a narrow band of frequencies nearly equal to the frequency f_n of circular revolution (equation 9).

Let us now follow the motion of two particles at positions P and Q with radii nr_1 and qr_1 respectively, revolving in anticlockwise sense round the centre O as in Figure 3. The frequencies of revolution at P and Q are given by equation (9) for the orbital number n or q. Let the particles at positions P and Q be as shown at the initial time $t = 0$. The relative positions of the points O, P and Q are as shown, with OP and OQ in an angular displacement ψ_o at the initial stage. In time t the line OP moves to OP_t through an angle of revolution ψ_n and line OQ moves to OQ_t through an angle of revolution ψ_q. The difference in angular displacement between the two particles, the instantaneous angle P_tOQ_t, is:

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

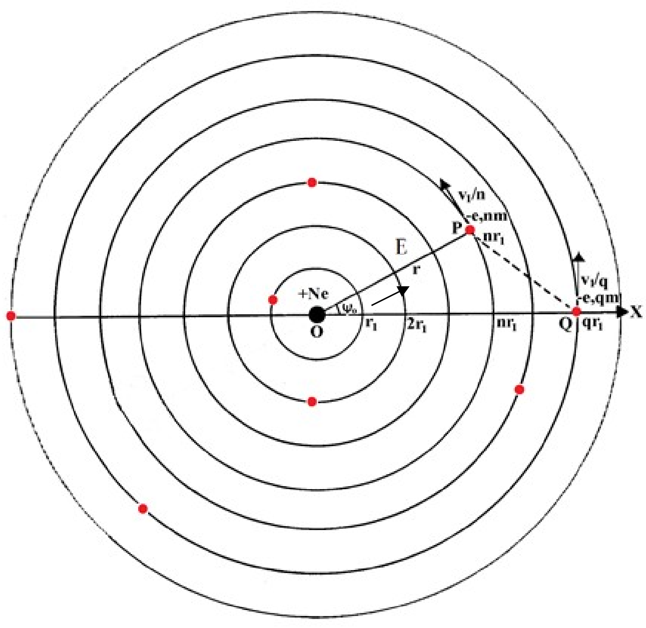

Figure 4: Seven circular orbits of proposed nuclear model of the hydrogen atom, consisting of N coplanar orbits each with a negatively charged particle revolving anticlockwise, in angle ψ, under the attraction in field **E** of nucleus of charge $+Ne$. A particle in the nth orbit has a multiple nm of the electronic mass m and the electronic charge $-e$, n being an integer > 0. The particle in the nth orbit revolves in a circle of radius nr_1 with velocity v_1/n and angular momentum $nmv_1r_1 = nL$

Angular frequency of oscillation between the particles at P and Q, at time t, is:

$$\frac{d\psi_t}{dt} = \frac{d\psi_n}{dt} - \frac{d\psi_q}{dt} = \omega_n - \omega_q = 2\pi f_n - 2\pi f_q = 2\pi f_{nq} \quad (11)$$

Combining equation (11) above with equation (9) where $f_n = cS/n^2$ and $f_q = cS/q^2$, gives f_{nq}, as:

$$f_{nq} = cS\left(\frac{1}{n^2} - \frac{1}{q^2}\right) \quad (12)$$

$$\frac{f_{nq}}{c} = \frac{1}{\lambda_{nq}} = S\left(\frac{1}{n^2} - \frac{1}{q^2}\right) \textit{ per meter} \quad (13)$$

Equation (13) also gives the wave number of radiation as a result of interaction between charged particles in the nth and qth orbit.

3.2 Stability of the nucleus in the nuclear model

In Figure 3, the nucleus of charge $+Q$ has N positrons and $\frac{1}{2}N(N + 1) - N = \frac{1}{2}N(N - 1)$ "unitrons", How can N positrons exist without exploding in mutual repulsion? The answer lies in the strong magnetic field created at the nucleus of the atom, by the revolving electrons in their circular orbits. The positive nuclear particles, supposed to lie as ring in the orbital plane and revolving in the same sense as the electrons, should be confined at the center under force of repulsion. On certain conditions of pressure and boiling-point temperature, the center falls apart, from solid to liquid to gas, forming the non-nuclear model of the atom of an element.

3.3 Heat generation in the nuclear model

In Figure 3, the nucleus of charge Q at the centre F_1 of stable circular orbit CDEF, rotates with its electric field $\mathbf{E}_p$ in the orbital plane, at angular velocity $\boldsymbol{\omega}$ perpendicular to the plane of the orbit. The rotation or spin of Q, causes a magnetic field $\mathbf{H}_p$ at P, distance as vector $\mathbf{r}$ in the orbital plane, such that:

$$\mathbf{H} = \varepsilon_o(\boldsymbol{\omega}\times\mathbf{r})\times\mathbf{E} = -r\varepsilon_o E\boldsymbol{\omega}$$

Lawrentz force on particle of charge $-e$ and mass nm moving in the nth orbit, with velocity $\mathbf{v}$ in a magnetic field of intensity $\mathbf{H}$, is given by:

$$\mathbf{F}_p = -e\mathbf{E} - e\mu_o(\mathbf{v}\times\mathbf{H}) = -e\mathbf{E} + reE\mu_o\varepsilon_o(\mathbf{v}\times\boldsymbol{\omega}) = -e\mathbf{E} + re\mu_o\varepsilon_o(v\omega)\mathbf{E} = -nm(v^2/r_n)\hat{\mathbf{u}} \quad (14)$$

where μ_o is the electric permeability, $(\mathbf{v}\times\boldsymbol{\omega})$ and unit vector $\hat{\mathbf{u}}$ are in the $\mathbf{E}$-direction.

In equation (14) decrease in force of attraction translates to increase in radius of revolution and decrease in potential energy for heat radiation. A revolving charged particle, in the nth orbit, contributes radiation at different intensity and frequency, the highest is with respect to the first orbit, $n = 1$.

4. Non-Nuclear Model of the Hydrogen Atom

The proposed non-nuclear model of the hydrogen atom consists of a concentric arrangement of N coplanar orbits. The orbits are equally spaced, each with two particles of charges $-e$ and $+e$ and the same mass nm revolving in the nth orbit round the centre of mass of the two particles. The non-nuclear model has no nucleus but an empty centre of mass. The equation of the orbit of motion of particle of mass nm, in the nth orbit, at distance r from the centre, is derived [20] as:

$$\frac{1}{r} = \frac{A}{n}\exp(-b\psi)\cos(\alpha\psi + \beta) + \frac{m\kappa}{nL^2} = \frac{A}{n}\exp(-b\psi)\cos(\alpha\psi + \beta) + \frac{B}{n} \quad (14)$$

where the excitement amplitude A and phase angle β are determined from the initial conditions, b *(decay factor)*, α *(rotation factor)* and $\kappa = e^2/16\pi\varepsilon_o$ are constants with nL as constant angular momentum, where n = 1, 2, 3…N orbits. Equation (14) should be compared with equation (8) for the nuclear model.

The exponential decay factor $(-b\psi)$, in equation (14), is a result of radiation of energy. The two charged particles will revolve, round their center of mass, in an unclosed (aperiodic) elliptic orbit with some cycles of revolutions, radiating energy, before settling down into the nth stable orbit, a circle of radius $nL^2/m\kappa$ (latus rectum of ellipse), until it is disturbed again. The energy radiated is equal to the difference between the change in potential energy and the change in kinetic energy. Emission of radiation makes all the difference in the motion of electrically charged particles in an electric field.

4.1 Initial elliptic orbit and final stable circular orbit

The initial orbit of revolution of an excited particle is an ellipse with two focuses F_1 and F_2, shown WXYZ in Figure 4. But, as a result of emission of radiation, the charged particle revolves in an unclosed orbit, in many cycles of revolution in angular displacement ψ, of increasing radius and decreasing speed, and emission of radiation, before settling in the final stable orbit, the red circle CDEF of center at the focus F_1 and radius $1/B = nL^2/m\kappa$ (the latus rectum) in Figure 4.

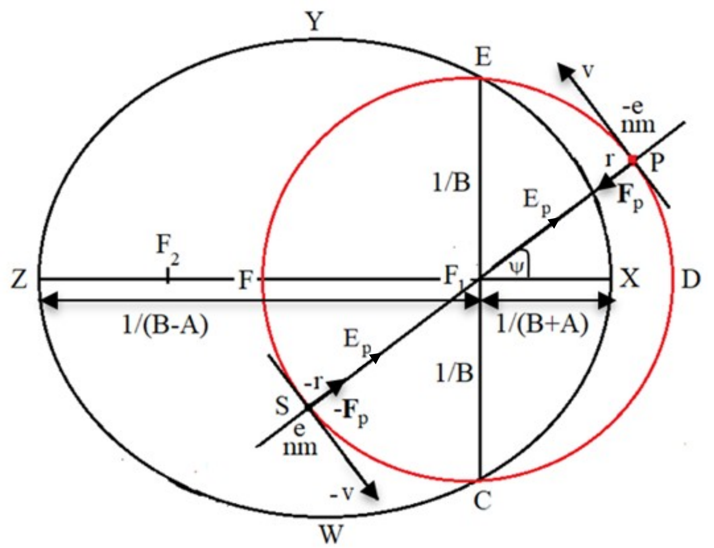

Figure 5: Free (Initial) ellipse WXYZ and stable circular orbit of revolution CDEF (red) of two particles of charges $+e$ and $-e$ and each of mass nm at P and S revolving with speed v and constant angular momentum $mnvr = nL$, in the nth orbit, under mutual attraction in electric field $\mathbf{E}_p$, round a circle with diameter as latus rectum EC and canter at focus F_1.

Figure 4 shows the free ellipse WXYZ of focuses F_1 and F_2. The *exponential decay factor* $q = 0$, *rotation factor* $\boldsymbol{\alpha} = 1$ and *phase angle* $\beta = 0$. The length ZX is the *major axis* and EC the *latus rectum* as diameter of the final stable circular orbit CDEF.

In the non-nuclear model, 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 a few stable orbits is shown in Figure 5.

The non-nuclear model of the hydrogen atom, in contrast to the nuclear model, has no nucleus, but an empty common centre of mass for all the particles in N orbits. In the non-nuclear model, there two oppositely charged particles revolving in an orbit, under mutual attraction.

4.2 Frequency of radiation

In the non-nuclear model, 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 orbits is shown in Figure 5. The non-nuclear model of the hydrogen atom, in contrast to the nuclear model, has no particle as a nucleus, but an empty common centre of mass for all the particles in N orbits.

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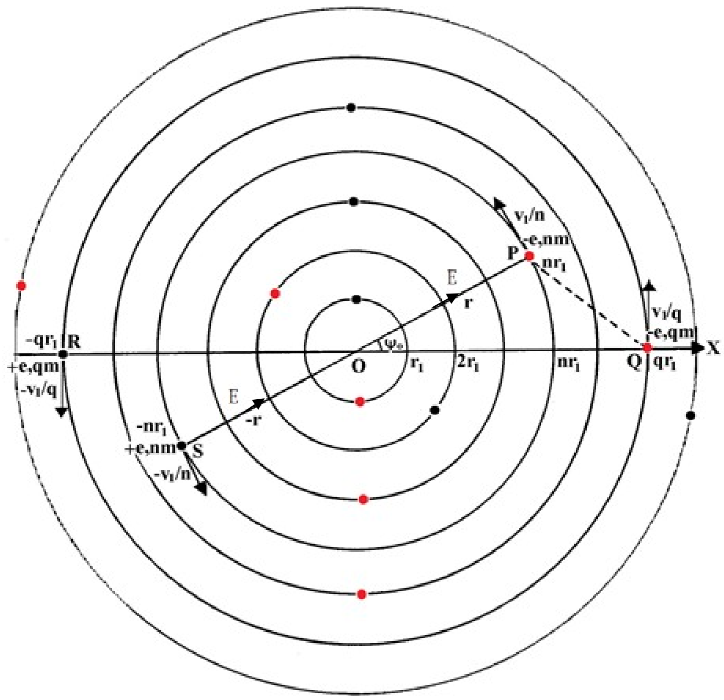

Figure 6: Seven circular orbits of non-nuclear model of hydrogen atom, of N coplanar orbits each with two equal but oppositely charged particles revolving anticlockwise, in angle ψ, under mutual attraction in field **E**. Each particle in the nth orbit has mass nm, with charges $-e$ and $+e$, n being an integer from 1 to N, m is electronic mass and $-e$ the electronic charge. The nth pair of particles revolves in a circular orbit of radius nr_1 , velocity v_1/n and angular momentum $nmv_1r_1 = nL$

The frequency of revolution of a particle moving with constant speed v_n in the nth stable orbit of Figure 5, a circle of radius r_n, is:

$$f_n = \frac{v_n}{2\pi r_n} = \frac{me^4}{16\pi n\varepsilon_o L}\frac{1}{2\pi\left(16\pi n\varepsilon_o L^2\right)} = \frac{me^4}{2\pi\left(16\pi\varepsilon_o\right)^2 L^3}\frac{1}{n^2} \qquad (15)$$

Putting $L = h/4\pi$, the angular momentum in the first orbit, gives equation (15) as:

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

where R is Rydberg constant. Equation (16), for the non-nuclear model, should be compared with equation (10) for the nuclear model.

4.3 The Balmer-Rydberg formula for the non-nuclear model

Let us 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 5. The frequencies of revolution at P and Q are given by equation (16) for the orbital numbers n or q. In Figure 5, 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 OP_t through an angle ψ_n, and let the line OQ move to OQ_t through an angle ψ_q. The difference in angular displacement, the instantaneous angle P_tOQ_t, is:

$$\psi_t = \psi_o + \psi_n - \psi_q \qquad (17)$$

The angular frequency of oscillation between particles at P and Q, is obtained by differentiating equation (17) with respect to time t, thus:

$$\frac{d\psi_t}{dt} = \frac{d\psi_n}{dt} - \frac{d\psi_q}{dt} = \omega_n - \omega_q = 2\pi f_n - 2\pi f_q = 2\pi f_{nq} \qquad (18)$$

Combining equation (18) above with equation (16) where $f_n = cR/n^2$ and $f_q = cR/q^2$, gives:

$$f_{nq} = cR\left(\frac{1}{n^2} - \frac{1}{q^2}\right) \qquad (19)$$

Equations (18) and (19) are possible by dealing with angular displacements in orbits, not quantum jump.

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

$$v_{nq} = \frac{f_{nq}}{c} = R\left(\frac{1}{n^2} - \frac{1}{q^2}\right) \qquad (20)$$

The particles revolve in their respective orbits as radiators. Interactions between the $2N$ particles, in the N orbits, result in the emission of radiation of discrete frequencies and wave numbers given by equations (19) and (20) respectively. Equation (20) is identical to equation (1), the Balmer-Rydberg formula for the spectral lines of radiation from the atom of hydrogen gas.

4.4 Number of orbits in the non-nuclear model

In measurements with a mass spectrometer, the hydrogen atom is found to be about 1836 times the mass m of the electron. The total number of revolving particles in N orbits, each containing two particles either of mass nm, is obtained from the sum of the natural numbers: $n = 1, 2, 3,\dots N$. Twice this sum, which carries the mass of the atom, gives $N(N + 1)m = 1836m$. Solving the quadratic equation gives $N = 42.35$, same as for nuclear model. The number N, which should be an integer, 42 or 43, is reasonable.

4.5 Heat generation in the non-nuclear model

In Figure 4, a revolving positive or negative particle of mass nm in the nth orbit, may spin with angular velocity $\boldsymbol{\omega}$ to create a magnetic field **H**, one at the location of another, as in the Positronium (Figure 1). Magnetic field **H** created by charge e with electric field $\mathbf{E}_p$, in the plane of the orbit, at velocity as vector product $2\mathbf{w}\times\mathbf{r}$, at the location of the other charge $-e$, distance $2r$ away, is given by:

$$\mathbf{H} = 2\varepsilon_o(\boldsymbol{\omega}\times\mathbf{r})\times\mathbf{E}_p = -2r\varepsilon_o E\boldsymbol{\omega} \qquad (21)$$

where $\boldsymbol{\omega}$ is perpendicular to $\mathbf{E}_p$. Lorentz force $\mathbf{F}_p$ on particle of charge $-e$ moving with orbital speed v, through the magnetic field of intensity **H**, in an electric field of intensity $\mathbf{E}_p$, is:

$$\mathbf{F} = -e\mathbf{E}_p - e\mu_o(\mathbf{v}\times\mathbf{H}) = -e\mathbf{E}_p + 2reE_p\mu_o\varepsilon_o(\mathbf{v}\times\boldsymbol{\omega}) = -e\mathbf{E}_p + 2re\mu_o\varepsilon_o(v\omega)\mathbf{E}_p = nm(v^2/2r)\hat{\mathbf{u}} \qquad (22)$$

where μ_o is the electric permeability, vector $(\mathbf{v}\times\boldsymbol{\omega})$ and unit vector $\hat{\mathbf{u}}$ are in the $\mathbf{E}_p$-direction.

Decrease of accelerating force in equation (22) causes increase in radius of revolution and decrease of potential energy for emission of heat radiation. Each charged particle, in the nth orbit, contribute to the atomic radiation at different frequency and intensity, with highest in the first orbit, $n = 1$.

5. Nuclear Model Versus the Non-Nuclear Model

The proposed nuclear model of the hydrogen atom has a nucleus of charge $+Ne$ and N coplanar orbits in each of which a particle of charge $-e$ and mass nm revolves. The total charge of the negative particles is $-Ne$, equal and opposite of the positive charges on the nucleus. The total mass of the N revolving particles is $\frac{1}{2}N(N + 1)m$, is the same as the mass of the nucleus.

The proposed non-nuclear model of the hydrogen atom has no nucleus, but an empty centre of mass round which particles revolve in N 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. The total mass of particles in the N orbits, with two particles in each orbit, is $N(N + 1)m$. The positive and negative electrical charges, in an atom, balance out exactly to form a stable particle. Thus, the nuclear model and the non-nuclear model of the hydrogen atom have the same number of orbits N and the same mass, equal to $N(N + 1)m$. The question now is: "What is the significance of these two different models of the hydrogen atom?"

It is suggested that the non-nuclear model is what obtains with the gas phase of hydrogen while the nuclear model exists with respect to the liquid and solid states. Let us now determine the relationship between the constant S as given by equation (9) for the nuclear model and the Rydberg constant R obtained from equation (16) for the non-nuclear model. The expression obtained, equal to the ratio of frequency g_n in the nuclear model and f_n in the non-nuclear nuclear model, for the nth orbit, is:

$$\frac{g_n}{f_n} = \frac{S}{R} = 16N^2 \tag{21}$$

where N is the same number of orbits for the nuclear and non-nuclear models. Frequencies of radiation f_n from the non-nuclear model are in the red and violet regions; for the nuclear model the frequencies g_n are in the x-ray and gamma-ray regions.

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

$$\frac{S_n}{r_n} = \frac{1}{4N} \tag{22}$$

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

$$\frac{w_n}{v_n} = 4N \tag{23}$$

6. Structure of other atom of Elements

The atomic numbers of the elements are 1 Hydrogen, 2 Helium, 3 Lithium, 4 Beryllium, 5 Boron, 6 Carbon, 7 Nitrogen, 8 Oxygen, 9 Fluorine, 10 Neon, up to the highest 92 Uranium, as naturally occurring with many isotopes – same atomic number and chemical properties but different atomic masses.

Hydrogen, the most common element, constitutes 90% of matter in the universe. The hydrogen atom is the simplest. The nuclear model of hydrogen atom, for the liquid or solid state, has N orbits each with one particle of charge $-e$ and mass nm, revolving in the nth orbit, with total mass as arithmetic sum $\frac{1}{2}N(N+1)m$, where $n = 1, 2, 3 \ldots N$. The non-nuclear model of hydrogen atom, for the gaseous state, has two particles of charges $-e$ and $+e$, each of mass nm, in total mass $N(N + 1)m$, revolving diametrically, under mutual attraction, round an empty center of mass.

The nuclear model of atoms of other elements, for solid state, has *N* orbits, each orbit with *Z* particles, each of charge *-e* and mass *nm*, revolving in the nth orbit, under the attraction of a nucleus, where *Z* is atomic number. For the non-nuclear model, there are *2Z* particles of charges *-e* and *+e*, both of mass *nm*, revolving under mutual attraction. Figures 6 to 12 show the configurations of nuclear and non-nuclear atomic models for Hydrogen, Helium, Lithium and Oxygen. Figure 12 is for oxygen, with $Z = 8$, and a nucleus of charge *+8Ne* and mass *4N(N+1)m*, equal to total mass of orbiting negative particles.

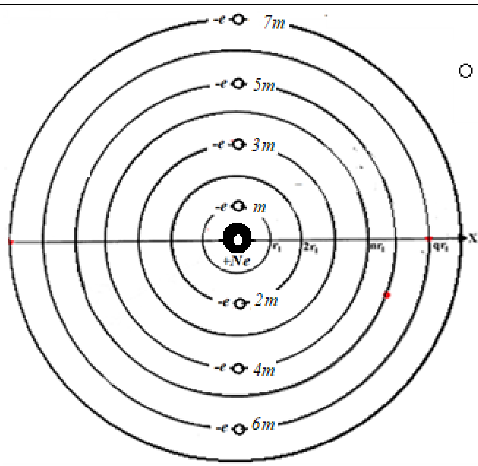

Fig. 6: First *7* of *N* orbits of nuclear model of hydrogen, nth orbit with particle of charge *-e,* mass *nm,* revolving under attraction of nucleus of charge *+Ne* and mass *½N(N + 1)m*.

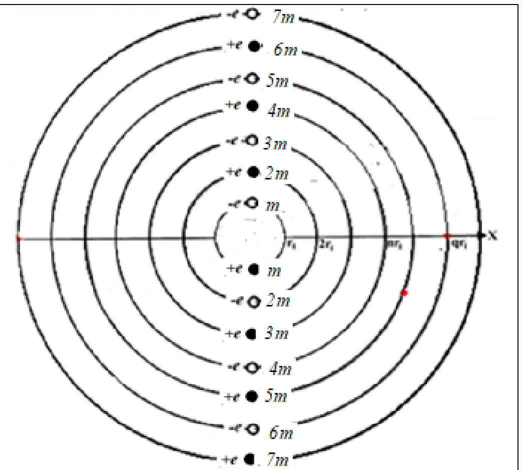

Fig. 7: First *7* of *N* orbits of non-nuclear model of hydrogen, the nth orbit with 2 particles of charges *-e* and *+e* and mass *nm*, revolving under mutual attractions, with total mass *N(N + 1)m*.

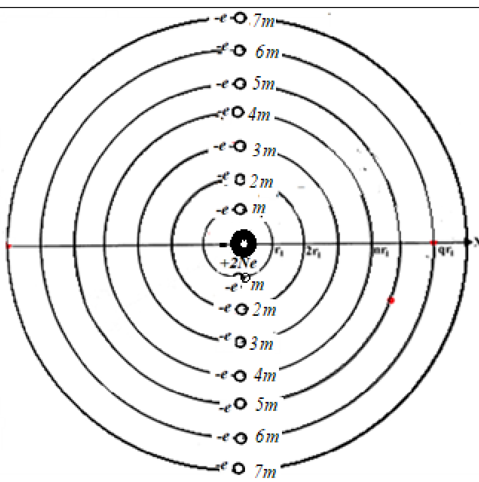

Fig. 9: First 7 of *N* orbits of nuclear model of helium, each orbit with *2* negative particles of mass *nm* revolving under attraction of nucleus of charge *+2Ne*, mass *½ZN(N + 1)m*

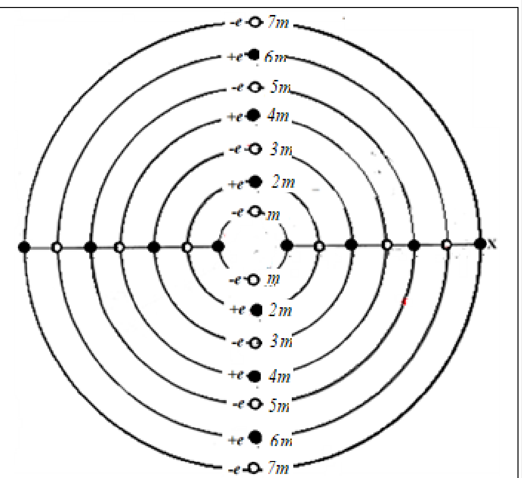

Fig. 9: First 7 of *N* orbits of of non-nuclear model of helium with 4 positive and negative particles each of mass *nm* in orbits, revolving under mutual attractions with total mass Z*N(N + 1)m*.

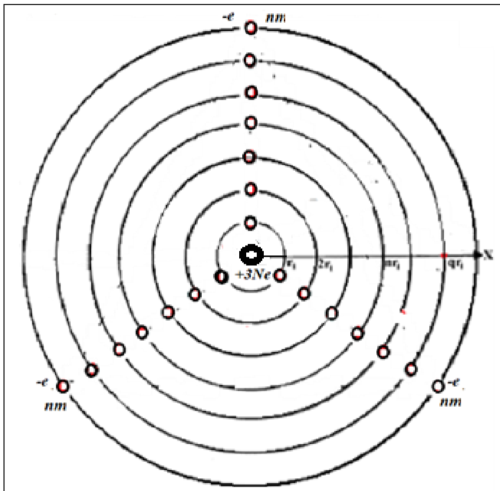

Fig. 10: First $n = 7$ of N orbits of nuclear model of lithium with 3 negative particles, each of mass nm revolving under attraction of nucleus of charge $+3Ne$ and mass $½N(N + 1)m$.

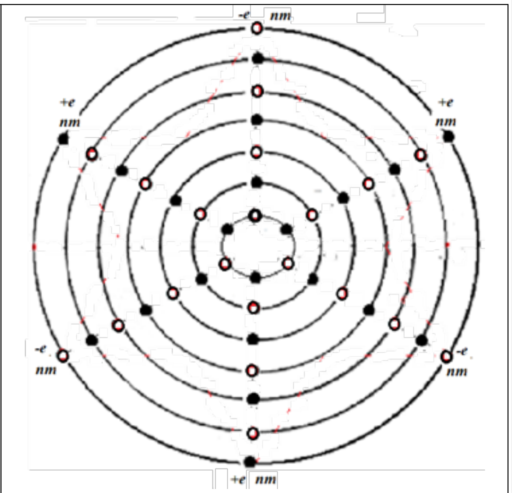

Fig. 11: First $n = 7$ orbits of non-nuclear model of lithium with 6 positive and negative particles each of mass nm, revolving under mutual attractions in total mass $N(N + 1)m$.

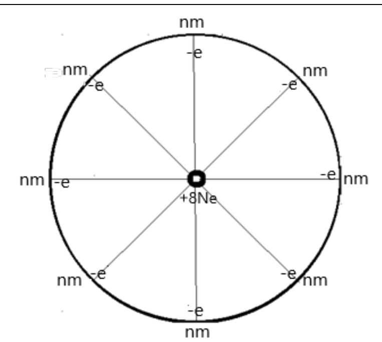

Fig. 12: The 7th orbit of nuclear model of oxygen with 8 particles, each of charge $-e$ and mass $7m$ in N orbits, under attraction of a nucleus of charge $+8Ne$ and mass $4(N + 1)m$.

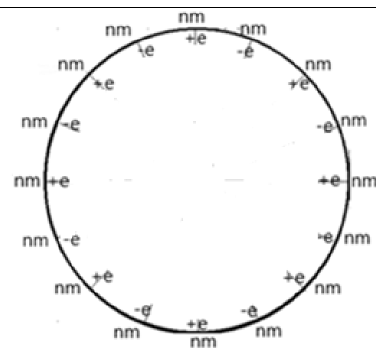

Fig. 13: The 7th orbit of non-nuclear model of oxygen atom with 16 particles of charges $+e$ and $-e$ and mass $7m$ in N orbits, revolving under mutual attractions with total mass $8(N + 1)m$.

7. Number of Neutral Particles in the Nucleus

Number of particles in the nucleus of hydrogen (protium) atom of N orbits is $½N(N + 1)$ of which N are electrically charged. As such, there should be $½N(N - 1)$ neutral particles each of electronic mass m. This is the number of neutral particles in the orbits of the non-nuclear model. The nth orbit has $(n – 1)$ neutral particles. A positronium, with one orbit ($n = N = 1$), has no neutral particle.

An isotope is an atom of the same element with the same atomic number Z and same chemical properties but different atomic masses as multiples of the total mass of the neutral particles. For an isotope, mass of particle in the nth orbit is $Z(ni)m$ for nuclear model and $2Z(ni)m$ for non-nuclear model, where i is an integer. Hydrogen atom, for example, has ($i=1$) protium, ($i=2$) deuterium and ($i=3$) tritium.

8. Results and Discussion

- Non annihilation of positron and electron in the positronium (Figure 1), on contact, created the "unitron" (Figure 2) as a neutral particle and basic constituent of matter.
- Existence of "unitron" as a neutral particle of mass m, same as the mass of positron or electron, made possible the creation of matter, with particles of mass nm, revolving in N coplanar orbits, where n is an integer: $1, 2, 3, \ldots N$ number of orbits.
- Explaining atomic temperature as due to the spinning of positrons and electrons composing the atom, is a new concept in physics.
- Expressions for the Balmer-Rydberg formula and the Rydberg constant (equations 3 and 4) for the proposed non-nuclear model of the hydrogen atom, are derived without recourse to Bohr's second postulate but with a modification of the first postulate. It is that *the magnitude of the angular momentum of a particle of mass nm, revolving in the nth orbit, is equal to* $nL = nh/4\pi$, where $h = 6.626 \times 10^{-34}$ J-sec. is the Planck constant. Quantization of angular momentum (nL) and radius of revolution $(nL^2/m\kappa)$ and inverse quantization of velocity (κ/nL) appear naturally as a consequence of discrete masses *(nm)*, being multiples of the electronic mass m, with n as an integer.
- Quantum numbers n, in the Balmer-Rydberg formulas (equations 13 & 20), gives radiation because of interaction between charged particles revolving in the nth and qth orbits.
- The quantum number n, in equations 13 & 20, is the same as the orbital number of an orbit of a revolving charged particle in the nuclear or non-nuclear model of the hydrogen protium atom.
- The angular momentum of a particle in the first orbit of the non-nuclear model, is $L = h/4\pi$ is a fundamental quantity equal 5.273×10^{-35} *J-sec*. It defines the Planck constant h in terms of angular momentum rather than "unit of action". Planck constant features prominently here, but Bohr's quantum mechanics is not required in describing discrete frequencies of radiation from the hydrogen atom.
- As a charged particle is disturbed from the nth stable circular orbit, it revolves in an unclosed elliptic orbit, with increasing or decreasing frequency of revolution and emission of radiation at the frequency of revolution, before reverting into the circular orbit. There should be a narrow spread in the frequencies of emitted radiation, around the frequency of circular revolution. This may explain the "fine structure" of the spectral lines of radiation from the atom of hydrogen gas.
- The radius of the first orbit $(n = 1)$ of the non-nuclear model of the hydrogen atom is obtained as $r_1 = \varepsilon_o h^2/\pi m e^2 = 5.292 \times 10^{-7}\ m$, the same as the **first Bohr radius** obtained, through quantum mechanics, for the nuclear model. The radius of the first orbit in the nuclear model is about $s_1 = 3.15\ x10^{-9}$, making the particles in the nuclear model more tightly packed by more than 160.
- 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 $u_1 = Ne^2/\varepsilon_o h$. Knowledge of nuclear charge $+Ne$, as may be obtained from experiment, is required to determine the radius $s_1 = \varepsilon_o h^2/4N\pi m e^2$ and speed u_1 of revolution (equations 16 and 17) in the nuclear model.

- The number N of planar orbits found to be 42, assumed to be the same for the nuclear and non-nuclear models, is reasonable.
- The nuclear model is reserved for the liquid or sold state of hydrogen and the non-nuclear model for the gaseous state. The Balmer-Rydberg formula for frequencies of radiation in the hydrogen atom spectrum, is for the gaseous state.
- A strong magnetic field, at the center of the nuclear model, is created due to the revolution of N electrons in the same sense. This should constrain a ring of N positrons, at the center, rotating in the same sense as the electrons.
- A question to be answered is why the nucleus is always positive. It may be because the Earth is negatively charged so that free electrons can exist. Our Sun might have been a positively charged Binary Star when its negative companion, situated where Jupiter now resides, disintegrated and the parts formed negatively charged planets orbiting in the same sense and almost in same plane.
- It may as well be that the radius a of the electron or positron is the smallest length in nature and the surface field is the strongest, making the structure of the basic particle indestructible.
- The non-annihilation of positronium and its conversion to a neutral particle, "unitron", with emission of gamma rays, should be what make possible the creation of atoms and matter.
- The paper identifies a neutral particle, same as the "unitron", in the atoms of matter.
- The electron, positron and neutral particle called "unitron", are supposed to have the same mass m and intrinsic energy $E = ½\ mc^2 = 2.047 \times 10^{-14}$ *joules*.

7. Conclusion

✓ The introduction of two models of the atom for the liquid and solid states of hydrogen or the gaseous state, each with N coplanar orbits, different from Rutherford's nuclear model, has been achieved with the frequency of emitted radiation related to the frequency of revolution of the charged particle, in a circular orbit, round a center of force of attraction.

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