RESURRECTION OF THE BOHR/SOMMERFELD THEORY OF ATOMIC STRUCTURE.

[2]

INCORPORATION OF THE MECHANICAL EFFECTS OF ELECTRON SPIN.

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ABSTRACT

The Bohr/Sommerfeld theory of atomic structure, as restated in [1], is herein further developed to incorporate the mechanical effects of electron spin.

1 Introduction.

Subsequent to the initial resurrection of the Bohr/Sommerfeld theory of atomic structure in [1], in which the electron is treated as a real physical particle, this paper continues the development of that theory by incorporating the mechanical effects of electron spin.

Electron spin is a completely separate motion from that of the orbital, having a separate rotational path, a circumferential one. For these reasons, electron spin must have associated with it, a separate matter wave from that of the main orbital rotation. This spin matter wave, in order for the spin motion to be stable must be independently quantised. The spin quantisation process, being unique will consequently result in a spin principle quantum number. The derivation of this is the subject of Section 3.0. The manner in which this then contributes to the emission spectra, is covered in Section 4.0 via discussion of the photon emission mechanism, and the development of the electron transition Selection Rules. Prior to these derivations however, it is necessary to address some preliminary factors to characterise the spin motion. The main one of these is the nature and origin of electron spin. This and other salient points are discussed in the next section.

2 The Characterisation of Electron Spin.

2.1 The Necessity for Electron Spin.

As this theory is one in which all particles are treated as real masses with real physical dimensions, it is necessary to establish the need for real physical spin. The main reason is of course the need to establish the means by which a spin magnetic dipole is generated, to interact with that generated by the orbital motion, to result in fine structure splitting. This will form the subject of the next paper. In addition, electron spin will also be shown to be instrumental in a possible mechanism for the initiation of electron orbital transitions. A subject which has not been properly addressed in any theory of electron structure to date. It will form the subject of further development and discussion in this, and a future paper in this series. Finally, electron spin is also known to be of fundamental importance in the existence of the Selection Rules. These are developed in detail in Section 4.0 below.

2.2 The Origin of Electron Spin.

It has been stated, [3], that the idea of a physically rotating electron possessing finite extensions can only be considered from a heuristic point of view. The reasons being that calculations of surface velocity would exceed the speed of light, if values of angular momentum and magnetic moment are to agree with those determined experimentally. However, it was shown in [4] that it is entirely possible for the spin circumference of a rotating body, to be accelerated to the speed of light while the mass remains finite. In fact it was postulated that as a result of this and the primary condition of existence in D_0, (see [7]), that in a corpuscular theory of atomic structure, it may very well be this mechanism that initiates an orbital transition and thus a spectral emission. This proposal will be addressed further in this paper. Hence the possibility that the surface of a spinning electron could exhibit a spin circumference velocity of the speed of light, (or more correctly, the terminal velocity of D_0), should not be the cause to reject the idea of a physically spinning electron in any theory of atomic structure. However, there are still problems with this approach. First, it means that subsequent to the formation of an atom, in which electron spin exists in one direction, there is no apparent mechanism for effecting spin reversals, as is evident in some electron orbital transitions. Also, it is evident that many orbitals can contain electrons with either direction of spin while others can contain electrons with only one direction. This is not a randomised feature and clearly infers that the orbital configurations extant within the atom, must contain a means by which this feature is controlled. Accordingly, it is considered likely that the origin of electron spin is also contained within the structure and embodies the mechanics which provide it with the above attributes. To address these apparent difficulties, a speculative mechanism for electron spin is presented as follows.

In [1], and the literature in general, it has been shown that the relativistic increase in mass of the orbiting electron, is instrumental in contributing to its fine structure emission/absorption spectra. It does not therefore seem unreasonable to consider other relativistic effects, as the possible cause of electron spin. Accordingly, it is suggested that due to the orbital velocity being a significant fraction of the velocity of light, as well as a relativistic increase in mass, the electron also experiences a Lorentz-Fitzgerald contraction in the direction of motion. Now consider Fig. 2.1 below.

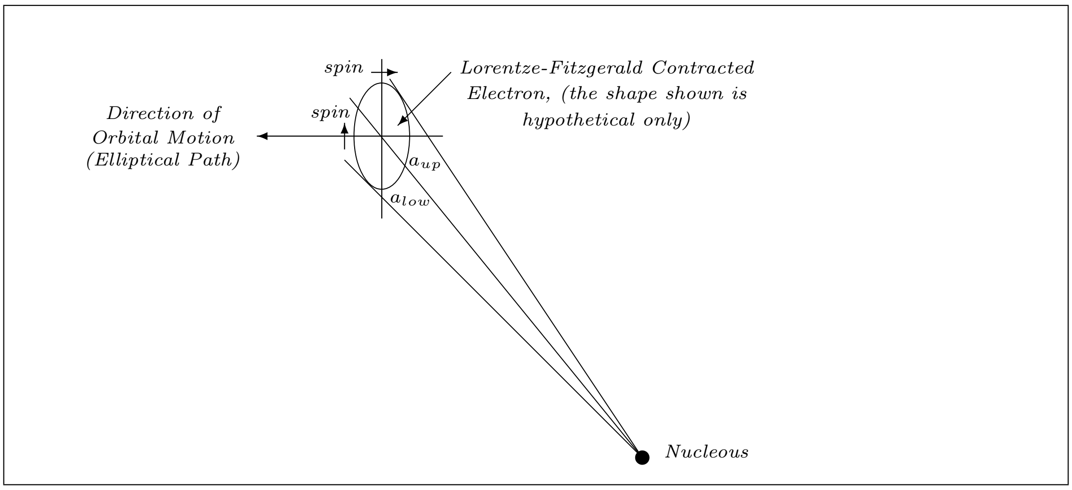

Fig. 2.1 - Lorentz-Fitzgerald Contraction of the Electron Along the Orbital Path.

Due to the Lorentz-Fitzgerald contraction in an elliptic orbit, the electron surface area subtended to the nucleus will be configured asymmetrically about the centre line joining them. e.g., in Fig. 2.1, the surface area a_{up} as opposed to the surface area a_{low}. Accordingly, the coulomb force of attraction between the two particles will also be asymmetrically distributed about the centre line. This will cause the electron to spin, in Fig. 2.1, in the direction shown. It would appear that the greater the orbital velocity, the greater will be the degree of contraction and hence the potential spin rate. However, the spin rate will be entirely governed by the quantisation requirements for the spin motion to be stable. In this respect it is noted that the mechanism causing spin takes place in a perfect vacuum. Therefore the torque imposed on the electron due to coulomb charge asymmetry experiences no resistance apart from inertia.

When the above process is applied around a complete elliptic orbit, the nature of the spin changes as shown in Fig. 2.2 below.

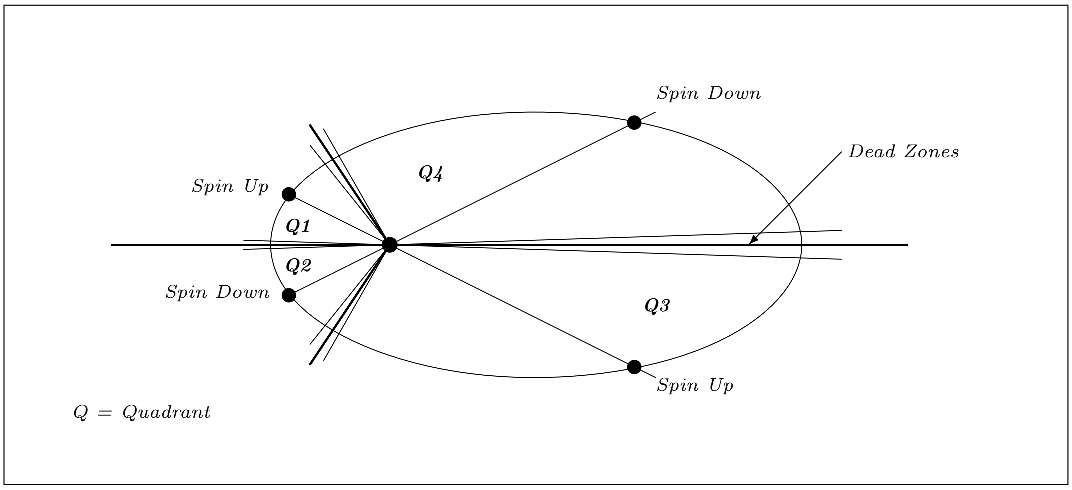

Fig. 2.2 - Electron Spin to Orbit Relationship.

As the electron orbits the nucleus, due to the eccentricity of the orbit, the surface area of the electron subtended at the nucleus changes orientation. The change is such that in quadrants 1 and 3 a clockwise, (spin-up), motion is induced while in quadrants 2 and 4 aa anti-clockwise, (spin-down), motion is induced. The shaded areas in Fig. 2.1 indicate possible dead zones where the asymmetry of distributed surface charge on the electron about the centre line is insufficient to induce spin. These dead regions would occur because at these points, the orbit path is almost/exactly normal to the radius vector to the nucleus, and the subtended angle of the electron surface is symmetrical about it. Thus it is obvious that in circular orbits, in which the radius vector from the nucleus to the orbiting electron was normal to the orbit path at all times, there would be no electron spin induction. However, when electron transitions from elliptic orbits to circular orbit paths occur, as a result of the conservation law of angular momentum, the electron would arrive in the circular orbit still possessing spin. The precise mechanism governing orbital transitions in circular, (and elliptic), orbits depends upon other factors in addition to electron spin, and will be discussed later in this and finalised in a future paper.

It is thus concluded that in all atomic orbits the electron will possess spin, in circular orbits, either spin-up or spin-down, and in most elliptic orbits in which spin induction occurs, both states.

One consequence of this proposed mechanism for electron spin induction, is that the driving force is identified as the asymmetry of the coulomb attraction between the nucleus and the orbiting electron. It is therefore necessary to determine what effect, if any, this would have upon the orbital principle quantum number.

Consider the possible, (non-relativistic), effects thus,

$$\Delta n_{(or,sp)} = m_0 \oint v_{sp} dl \tag{2.1}$$

where

$\Delta n_{(or,sp)}$ is a possible orbital principle quantum number variation due to the effects of electron spin.

v_{sp} is the velocity of the mass effective radius of the electron in axes of D_0 due to spin.

and where the integration path is that of the orbit.

Assume for simplicity, but with no loss of generality, that the orbit is "near" circular so that in (2.1) the orbit path elemental may be approximated by

$$dl \cong r d\phi \tag{2.2}$$

Eq.(2.1) then becomes

$$\Delta n_{(or,sp)} = m_0 \int_0^{2\pi} \omega_{sp} \Gamma_{gyr} r d\phi \tag{2.3}$$

where

Γ_{gyr} is the radius of gyration of the electron.

Eq.(2.3) reduces to

$$\Delta n_{(or,sp)} = \frac{M_{sp}\Gamma_{gyr}}{r} \int_0^{2\pi} \left(\frac{d\psi}{d\phi}\right) d\phi \tag{2.4}$$

Where

ψ is the electron spin angle

ϕ is the electron orbit angle

M_{sp} is the non-relativistic spin angular momentum.

now consider the term $(d\psi/d\phi)$, treating spin-up as positive.

In quadrant 1, if the electron spins k_1 times in traversing that quadrant, then

$$\left(\frac{d\psi}{d\phi}\right)_1 = +k_1 \tag{2.5}$$

Similarly, for the other three quadrants

$$\left(\frac{d\psi}{d\phi}\right)_2 = -k_2; \quad \left(\frac{d\psi}{d\phi}\right)_3 = +k_3; \quad \left(\frac{d\psi}{d\phi}\right)_4 = -k_4 \tag{2.6}$$

so that

$$\left(\frac{d\psi}{d\phi}\right)_{or} = +k_1 - k_2 + k_3 - k_4 \tag{2.7}$$

But by orbit quadrant symmetry

$$\begin{gathered} Quadrant\ 1 \equiv Quadrant\ 2 \\ Quadrant\ 3 \equiv Quadrant\ 4 \end{gathered} \tag{2.8}$$

so that

$$+k_1 - k_2 = 0 \quad and \quad = +k_3 - k_4 = 0 \tag{2.9}$$

Therefore in (2.7)

$$\left(\frac{d\psi}{d\phi}\right)_{or} = 0 \tag{2.10}$$

and so in (2.1), (2.3) and (2.4)

$$\Delta n_{(or,sp)} = 0 \tag{2.11}$$

Therefore, even though the electron spin mechanism proposed here is effectively driven by the nucleus/electron coulomb interaction asymmetry, it does not affect the quantised orbital energy.

Two final points, first, with spin reversals taking place within all the elliptic orbitals, there would also be reversals of spin angular momentum and spin quantum number, (see next Section). This would then, in most cases, (governed by the Selection Rules, see Section 4), permit transitions from these orbitals with either spin direction. Secondly, it is important to note that the effect described here would also cause the nucleus to spin.

2.3 Relativistic Mass Correction Due to Spin.

Prior to the derivation of the quantisation of electron spin, it is necessary to decide how its relativistic mass increase effect should be treated. Accordingly, it is also necessary to review how relativistic mass increase was treated in the quantisation of the orbital motion in [1] and determine whether the relativistic mass increase due to the spin motion needs to be incorporated in that quantisation process.
The simple answer to these questions is that the relativistic mass increases due to these two separate motions do not cross quantise. The reason is as follows. The principle orbital quantum number n, is derived from the single valuedness of the electron matter wave around the orbit path. It was shown in [2] that this matter wave is a representation of the kinetic energy of the electron in its orbital motion. The spin motion does not contribute to the orbital kinetic energy because it is a completely independent motion that must be separately quantised. Hence the relativistic mass of the electron used to determine the principle quantum number, and therefore the azimuthal quantum number, is only that due to the orbital motion. Consequently, the relativistic mass increase of the electron due to its spin motion does not influence the fine structure emission spectra.
As a result, the bound energy equation of the spinning, orbiting electron from which emission spectra can be derived, magnetic effects excluded, is still represented by [1], Eq.(2.24) and is not altered by the mechanical effects of spin.
That is not to say that these separate motions do not mechanically combine at all. The overall relativistic mass increase of the spinning, orbiting electron does indeed contribute to the total mass of the atom, [4], Eq.(2.56) refers. It is only in the quantisation process that the motions must be treated separately.

3 The Quantisation of Electron Spin and the Condition for Photon Emission.

3.1 Electron Spin Quantisation.

Electron spin, being an entirely separate motion from the orbital, will therefore have associated with it, a separate matter wave around its closed path, the spin circumference, the wavelength of which, for the spin motion to be stable must be single valued. It will therefore have associated with it a spin principle quantum number. This can be derived simply as follows. Utilising [2], Eq.(2.11)

$$n_{sp}h = \oint m^*_{sp} v'_{sp} dl_{sp} \tag{3.1}$$

Where

n_{sp} is the spin quantum number.

v'_{sp} is the spin velocity of the electron at its mass effective radius in axes attached to the electron.

m^*_{sp} is the relativistic mass of the electron due to its spin.

dl_{sp} is the spin path elemental

Expanding v'_{sp} and dl, (3.1) becomes

$$n_{sp}h = \int_0^{2\pi} m^*_{sp}\omega'_{sp}\Gamma^2_{gyr}d\psi \tag{3.2}$$

Where

ω'_{sp} is the spin rate in axes attached to the electron.

Γ_{gyr} is the radius of gyration of the electron.

ψ is the spin angle.

Eq.(3.2) integrates to

$$M^*_{sp} = \frac{n_{sp}h}{2\pi} \tag{3.3}$$

Where

M^*_{sp} is the relativistically corrected spin angular momentum.

Note that the relativistic mass increase due to spin has not been expanded out in the above derivation because its effect remains on the spin path and can be treated integrally with the rest mass.
Because n_{sp} is a principle quantum number its values must differ by an integer. Also because there are only two directions of spin, n_{sp} can take only two values, identical in magnitude. To meet both of these two limitations simultaneously, n_{sp} is restricted to the values of $\pm 1/2$. Thus

$$n_{sp} = \pm 1/2 \tag{3.4}$$

3.2 The Condition for Photon Emission.

It was shown in [4] that due to the distributed nature of matter in a spinning body it was possible for the spin circumference to achieve the terminal velocity in D_0, (the velocity constant c, $\sim$ the velocity of light), while the mass was still finite. It was subsequently shown that should the spin rate be further increased, to avoid the spin circumference exceeding the terminal velocity, it must shed the increased kinetic energy by radiating it in the form of electromagnetic radiation, (a photon emission), from the spin circumference. The frequency and wavelength were, in accordance with Planck's quantum law to be proportional to the energy input causing the increased spin rate. In the case of electron orbital transitions and associated spectral emissions it is proposed that it is this mechanism that is responsible for the photon emissions that initiate such transitions.
To support this proposal it is necessary to show that within atomic structure the electron, by virtue of its spin characteristic, is capable of inducing this mechanism. First, to prove that it is the spin of the electron that is responsible, and not some attribute of its orbital motion, it is known from relativistic theory that the addition of two independently driven velocities of any object is given by

$$v = \frac{v_1 + v'_2}{1 + \frac{v_1 v'_2}{c^2}} \tag{3.5}$$

Where

v_1 is the velocity of moving axes in D_0.

v_2' is the velocity of some object in the moving axes.

v is the velocity of the object in D_0.

In the case of some random point on the circumferential surface of a spinning electron in an orbital, (3.5) is restated as

$$v = \frac{v_{or} + \omega'_{sp}\Gamma_e}{1 + \frac{v_{or}\omega'_{sp}\Gamma_e}{c^2}} \tag{3.6}$$

Where

v is now the velocity of the random point on the circumferential surface of the electron.

v_{or} is the translational velocity of the electron in its orbit of the nucleus.

ω'_{sp} is the spin rate of the electron in axes attached to it.

Γ_e is the physical radius of the electron at the spin circumference.

From (3.6) it is easily seen that for $v = c$, then either

$$v_{or} = c \quad or \quad \omega'_{sp}\Gamma_e = c \tag{3.7}$$

For the purpose of photon emission initiation the first part of (3.7) can be discounted because this would incur the electron mass becoming infinite and its orbital consequently unstable. It is therefore only via the second part of (3.7) that the circumferential surface of the electron can achieve "light" velocity, and thereby initiate a photon emission and therefore an orbital transition.

It is now necessary to prove that this condition will actually be achieved by an electron due to its spin. To show this, it is first necessary to pre-empt results from a future paper. They concern the physical configuration of the electron. In order to exhibit a magnetic dipole of the correct strength, it will be shown in the next paper that the electron's configuration must be that of a very thin wall spherical shell, the outer surface of which carries the electric charge. The angular momentum of such a shell is derived in Appendix A, and the result of equating this to the spin angular momentum quantum criteria is then

$$M^*_{sp} = \frac{{}^2\!/_3 m_0 \omega'_{sp}\Gamma_e^2}{\left(1 - {}^4\!/_5 \frac{\omega'^2_{sp}\Gamma_e^2}{c^2}\right)^{1/2}} = \frac{n_{sp}h}{2\pi} \tag{3.8}$$

Note: M^*_{sp} in (3.8) is a second order relativistic approximation but adequate for the purpose here.

Solving (3.8) for ω'_{sp} gives

$$\omega'_{sp} = \frac{n_{sp}h}{2\pi\Gamma_e\left({}^4\!/_9 m_0^2\Gamma_e^2 + {}^1\!/_5 \frac{n_{sp}^2 h^2}{\pi^2 c^2}\right)^{1/2}} \tag{3.9}$$

Putting in values, (see [1], Appendix B and with Γ_e = 2.81794033E-13), gives

$\omega'_{sp} = 1.189379662E + 23$ radians/sec.

so that

$\omega'_{sp}\Gamma_e = 3.351600525E + 10$cm/sec

which is 1.117967846c. Thus for the electron to meet its spin angular momentum quantum criteria it would be necessary for its spin induced circumferential velocity to exceed the velocity of light. This confirms that electron spin is capable of inducing photon emissions and electron orbital transitions via the mechanism proposed above.
This appears to be an anomalous result in line with the statement in Section 2.1 from [3], in that in satisfying (3.8) and (3.9), the criterion of existence of the electron in D_0 would be contravened. However, in a future paper, in which the transition mechanism is finalised, it will be shown that the above "potential" anomalous result is central to the workings of this mechanism.

4 Basic Electron Transition Geometry and the Selection Rules.

It is in the characterisation of the Selection Rules of electron transitions, that the mechanical aspects of electron spin have another important effect. The geometry of photon emission and electron shell/orbital transitions is proposed as follows.
In a similar manner to the Compton effect, as a result of emitting a photon at the initiation of a transition, the electron will recoil in the opposite direction to the emission in accordance with the law of conservation of momentum. Fig. 4.1 below presents a pictorial representation.

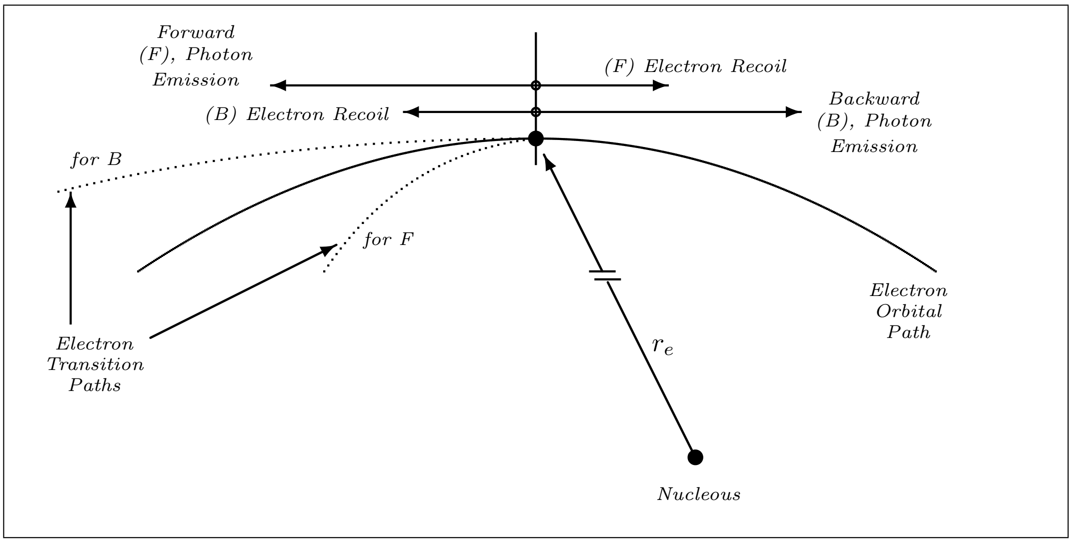

Fig. 4.1 - Basic Photon Emission/Electron Transition Geometry

The direction of photon emission can only be tangential to the orbital path, forward or backward, because they are the only directions in which the electron can impart momentum to the photon. Thus at the initiation of an electron transition, it imparts to the outgoing photon one or more quanta of kinetic energy, thereby causing the electron to fall to a lower shell. The momentum thereby imparted to the photon causes the electron to lose, (forward photon emission, backward electron recoil), /gain, (backward photon emission, forward electron recoil), that same amount of momentum such that its orbital angular momentum is reduced/increased by one quanta. Thus when the electron falls to a lower shell, the orbital it inserts into can only be one of a higher or lower orbital angular momentum by exactly one quanta, than in the emission shell. The transition to a lower shell orbital of the same angular momentum is therefore automatically excluded. i.e. $\Delta n_\phi^* = 0$ is not possible. Similarly, a change of n_ϕ^* of greater that ± 1 quanta is also excluded. The electron transition Selection Rule governing orbital angular momentum changes is thus given simply but exactly by

$$\Delta n_\phi^* = \pm 1 \tag{4.1}$$

as stated in [1], Eq.(3.47).

The transition path of the electron from the emission shell/orbital will, in view of the tangential nature of the recoil, be tangential to the orbital path. Also, during the transition, the motion of the electron is still mostly governed by the central coulomb force, and the transition path will therefore be degenerative. Insertion of the electron into the lower shell must also be tangential to the applicable orbital, because there would be no external influence affecting this part of the transition, and it must therefore be a smooth event. As a consequence of all the above, it would be expected that electron transition geometry would be one of the two types shown in Fig. 4.2.

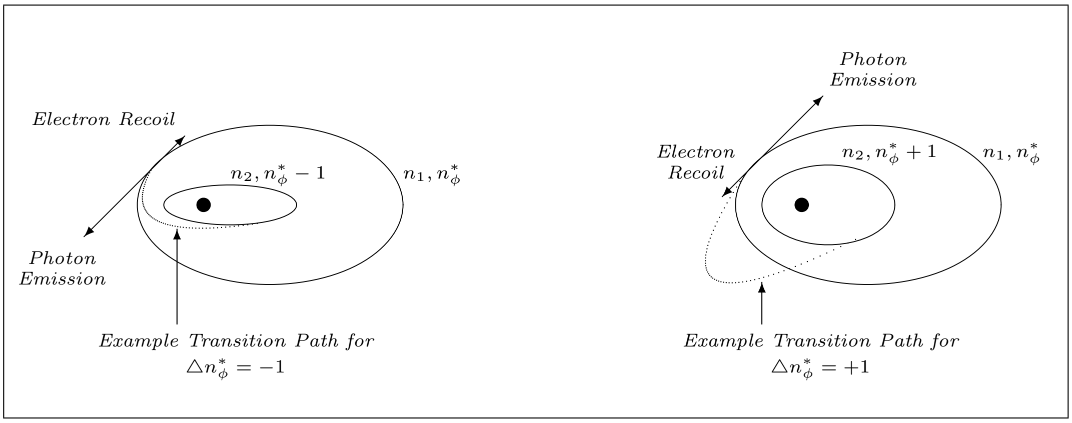

Fig.4.2 - Basic Electron Transition Geometry, (Conceptual)

It is now possible to determine the manner in which electron spin enters into the Selection Rule configuration. Fig.4.3 below presents a more detailed version of Fig.4.2 in which the direction of electron spin has been added in each quadrant. This of course assumes that the nature of electron spin is as proposed in Section 2. The formal adoption of this mechanism as the cause of electron spin has been made at this point, because that mechanism incorporates a natural means by which transitional spin reversal occurs, and this feature is seen to occur in empirical data, i.e.[5].

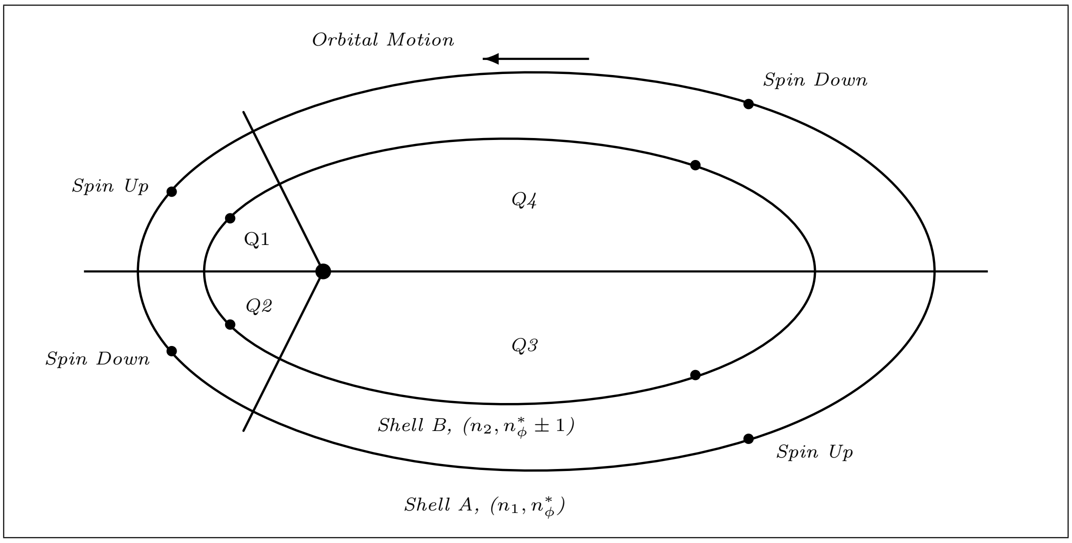

Fig.4.3 - Electron Transition Characteristics, (Conceptual).

Assume that electron transitions can occur from any quadrant on shell A to some other quadrant on shell B. The following tables and explanatory notes detail the characteristics of those transitions that are "permitted" and those that are not. It is in these tables that the inner quantum number is introduced as

$$n_j = n_\phi^* + n_{sp} \tag{4.2}$$

The primary significance of n_j will become apparent in the next paper in which the magnetic effects of electron spin are considered.

(i) Permitted :- $\Delta n_\phi^* = -1$, transitions for $1 < n_\phi^* < n$.

Type	Transition Start				Transition End				Q.N Changes		
	Quad't	n_ϕ^*	$\boldsymbol{n_{sp}}$	$\boldsymbol{n_j}$	**Quad't**	n_ϕ^*	$\boldsymbol{n_{sp}}$	$\boldsymbol{n_j}$	Δn_ϕ^*	$\Delta \boldsymbol{n_{sp}}$	$\Delta \boldsymbol{n_j}$
1	A1/A3	n_ϕ^*	+1/2	$n_\phi^* + 1/2$	B3/B1	$n_\phi^* - 1$	+1/2	$n_\phi^* - 1/2$	-1	0	-1
2	A2/A4	n_ϕ^*	-1/2	$n_\phi^* - 1/2$	B3/B1	$n_\phi^* - 1$	+1/2	$n_\phi^* - 1/2$	-1	+1	0
3	A2/A4	n_ϕ^*	-1/2	$n_\phi^* - 1/2$	B4/B2	$n_\phi^* - 1$	-1/2	$n_\phi^* - 1 1/2$	-1	0	-1

(ii) Permitted :- $\Delta n_\phi^* = +1$, transitions for $1 < n_\phi^* < n$.

Type	Transition Start				Transition End				Q.N Changes		
	Quad't	n_ϕ^*	$\boldsymbol{n_{sp}}$	$\boldsymbol{n_j}$	**Quad't**	n_ϕ^*	$\boldsymbol{n_{sp}}$	$\boldsymbol{n_j}$	Δn_ϕ^*	$\Delta \boldsymbol{n_{sp}}$	$\Delta \boldsymbol{n_j}$
4	A1/A3	n_ϕ^*	+1/2	$n_\phi^* + 1/2$	B3/B1	$n_\phi^* + 1$	+1/2	$n_\phi^* + 1 1/2$	+1	0	+1
5	A1/A3	n_ϕ^*	+1/2	$n_\phi^* + 1/2$	B2/B4	$n_\phi^* + 1$	-1/2	$n_\phi^* + 1/2$	+1	-1	0
6	A2/A4	n_ϕ^*	-1/2	$n_\phi^* - 1/2$	B4/B2	$n_\phi^* + 1$	-1/2	$n_\phi^* + 1/2$	+1	0	+1

(iii) Not Permitted :- $\Delta n_j = \pm 2$.

Type	Transition Start				Transition End				Q.N Changes		
	Quad't	n_ϕ^*	$\boldsymbol{n_{sp}}$	$\boldsymbol{n_j}$	**Quad't**	n_ϕ^*	$\boldsymbol{n_{sp}}$	$\boldsymbol{n_j}$	Δn_ϕ^*	$\Delta \boldsymbol{n_{sp}}$	$\Delta \boldsymbol{n_j}$
7	A1/A3	n_ϕ^*	+1/2	$n_\phi^* + 1/2$	B2/B4	$n_\phi^* - 1$	-1/2	$n_\phi^* - 1 1/2$	-1	-1	-2
8	A2/A4	n_ϕ^*	-1/2	$n_\phi^* - 1/2$	B3/B1	$n_\phi^* + 1$	+1/2	$n_\phi^* + 1 1/2$	+1	+1	+2

Current theory, [6], states that these transitions are excluded because they incur a change of total angular momentum of ±2, (i.e.$\Delta n_j = \pm 2$). However, because the orbital and spin motions of the electron are entirely separate, there should be no quantum reason why the change in their angular momenta could not be in the same direction resulting from an electron transition. This statement is just as applicable in the theory proposed here, with the cause of electron spin as described in Section 2, as in any other theory. The reason for the exclusion of these transitions is not considered to be the Δn_j result, which is considered to be "co-incidental", but rather a result of electron transition geometry restrictions. First consider transition type 7 above in relation to Fig. 4.2. For a $\Delta n_\phi^* = -1$ degenerative trajectory, it is proposed that it would not be possible for the electron to make a tangential transition from quadrants A1 or A3 into B2 or B4. The degeneracy of the transition path would be such as to allow a tangential insertion only into B3 or B1, i.e. a type 1 transition. The same comment applies to transition type 8 for a $\Delta n_\phi^* = +1$ transition where for the resulting path only a type 6 is possible. Confirmation of this proposed reason for the exclusion of the $\Delta n_j = \pm 2$ transitions would necessitate a detailed derivation of the respective orbit and transition paths.

(iv) Not Permitted :- To $n > 2$, $n^*_\phi = 1$, (s orbitals), $\Delta n^*_\phi = +1$.

Transitions to a s orbital for which $\Delta n^*_\phi = +1$ are excluded because this would mean a transition from a $n^*_\phi = 0$ orbital, i.e. a pendulum orbit and these were proven in [1] to be excluded in atomic structure. Therefore, only transitions for which $\Delta n^*_\phi = -1$ are possible, with one exception. Transition type 3 is also excluded because it would mean that in the receiving s orbital. n_j would be < 1, $(= +1/2)$, and by de Broglie's hypothesis $n_j \geq 1$. This has the important consequence that in the receiving s orbital only electrons with $n_{sp} = +1/2$ can make a transition insertion. Because s orbitals are elliptical and therefore subject to spin induction, this raises an apparent anomaly when the inserted electron orbits to the next quadrant, and the spin changes direction. This is discussed below in (vi).

(v) Not Permitted :- From $n > 2$, $n^*_\phi = 1$, (s orbitals), $\Delta n^*_\phi = -1$.

Transitions from an s orbital for which $\Delta n^*_\phi = -1$ are not permitted because this would mean a transition to a $n^*_\phi = 0$ orbital, i.e. a pendulum orbit and these were proven in [1] to be excluded in atomic structure. Therefore only transitions for which $\Delta n^*_\phi = +1$ are possible with one exception. Because only electrons with $n_{sp} = +1/2$ can exist in a s orbital, transition type 6 is also excluded.

(vi) Not Permitted :- From $n = 2$, $n^*_\phi = 1$.

There are no transitions possible from this one orbital. This is because a $\Delta n^*_\phi = -1$ transition would result in a n = 1, $n^*_\phi = 0$ pendulum orbit which were proven to be excluded in [1]. Transitions for which $\Delta n^*_\phi = +1$ are also excluded because there is no orbital in the $n = 1$ shell for which $n^*_\phi = 2$, and it would otherwise mean a transition from an orbital with $n^*_\phi = 0$, a pendulum orbit. However, electrons can make a transition insertion into this orbital with $n_{sp} = +1/2$, (into a spin-up quadrant), and so it would appear that such an electron would presumably remain there until excited up through the shells again. However, in the next paper, which deals with magnetic effects, it will be shown that subsequently an electron in this orbital will quite naturally make a smooth transition into another orbital in the same shell, (with zero energy change), from which it can make a normal inter-shell transition to the ground state. This intra-shell transition occurs as the electron's spin changes as it traverses into a spin-down quadrant in this s orbital. This feature also applies in (iv) above to avoid the apparent anomaly discussed briefly there.

It is clear from the above tables and exclusion discussions that the Selection Rules stated in terms of n_j are,

$$\Delta n_j = 0, \ \pm 1 \tag{4.3}$$

However, neither (4.1) nor (4.3) are universal as both are only applicable conditionally as shown in (iii), (iv), (v) and (vi) above. The Selection Rules will be further refined when spin-orbit magnetic coupling is introduced in the next paper.

5 Conclusions.

In this second paper concerning the resurrection of the Bohr/Sommerfeld theory of atomic structure, the primary objective was to incorporate the mechanical aspects of electron spin. The accomplishment of this objective can be summarised as follows.

5.1 Electron Spin Cause.

Because this theory is one in which the electron especially is treated as a real physical particle, and is postulated to possess real physical spin, it is necessary to also propose a cause of that spin. Also, because it has been "established" from empirical data that certain orbital transitions involve a change in the direction of spin, it is necessary that any proposed mechanism for electron spin must include a natural means to induce spin reversals. The mechanism proposed here, based upon the Lorentz-Fitzgerald relativistic contraction of the electron due to its high orbital velocity, meets both of the above requirements without incurring anomalies in the energy or emission characteristics of the atom.

5.2 Spin Angular Momentum Quantisation.

The quantisation of electron spin was accomplished in an identical manner to that of the principle quantum number for the orbital motion in [1]. This was possible because the two motions, albeit driven by the same source are completely independent. Consequently the spin quantum number must be treated as a principle quantum number in its own right. This helped to define its unique value.

5.3 Spin Mechanical Effects.

Having established the need, a proposed mechanism and the quantisation of electron spin, it was possible to establish the mechanical effects of this motion on the spectral signature of the atom.

5.3.1 Electron Orbital Transition Initiation.

The first effect is the inherent condition that causes an electron to initiate an orbital transition. Irrespective of the direction of the spin, its magnitude is sufficient to cause the circumferential velocity to exceed the terminal velocity of D_0, ($\sim$ the velocity of light). The electron will then shed a number of energy quanta in the form of a photon emission to avoid that anomaly. The direction of photon emission does not appear to depend upon the direction of electron spin because both forward and backward emissions can take place from an electron with either spin direction. This is a question which would need further investigation. The Compton recoil that the photon emission imparts to the electron then determines the nature of the change to its orbital angular momentum and spectral emission. Despite the detail that has been presented here on this effect, the mechanism so described is still incomplete. It will be finalised in a future paper in which the cause of the Lamb Shift is introduced.

5.3.2 Spin Relativistic Mass Increase.

The mass increase incurred as a result of electron spin will be relativistically significant because of the high spin rate, such that the quantum criteria level is approached. This mass increase augments that due to the orbital motion to result in the total relativistic mass of the electron. However, in determining the orbital path rotation due to relativistic effects it is only that part of the relativistic mass increase due to the orbital motion that is taken into account. This is because the matter wave associated with that motion, and used in the determination of the principle and azimuth quantum numbers, is a representation of the kinetic energy of the orbital motion only. The spin relativistic mass increase is similarly treated in isolation when quantising that motion. The consequence is that although the spin relativistic mass increase contributes to the overall mass increase of the electron, and therefore the atom, it does not contribute to the electron's orbital bound energy and is therefore not an influence in the spectral signature.

5.3.3 Mechanical Spin Energy.

In a similar manner to the relativistic mass increase discussed above, the mechanical spin energy of the electron, while contributing to the overall energy of the atom, would not form part of the orbital bound energy of the electron. It would not therefore be involved in defining spectral emission wavelengths.

5.3.4 **Selection Rules.**

In treating the electron as a real physical particle, it has been possible to derive, in detail, the Selection Rules for electron orbit shell transitions, in terms of orbit geometry and the direction of photon emission. All of the so-called permitted orbit transitions have been so derived. This includes those for which a spin reversal is involved. The reason for the appearance/non-appearance of spin reversal is also clear and is seen to be a consequence of the spin relationships to the orbital quadrants involved in the transition. Furthermore, for those transitions that are not permitted, the reasons have also been determined. The only one for which a potential disagreement exists between the current quantum theory and that proposed here is for those excluded transitions for which $\Delta n_j = \pm 2$. This condition exists because the spin reversal incumbent in these potential transitions incurs a spin angular momentum change that is in the same direction as the associated orbital angular momentum change. Because the spin and orbital motions are completely separate there should not be any quantum reason why the angular momentum associated with these two motions could not change in the same direction during a transition. The exclusion of the two transitions in question is therefore believed to be for orbital geometrical reasons alone. The Δn_j condition must obviously be associated with this geometrical limitation but is not believed to be the primary factor involved.

The overriding conclusion drawn from the results of this paper, is that the mechanical aspects of the spin of a real physical electron particle have been satisfactorily incorporated into the resurrected Bohr/Sommerfeld theory of atomic structure presented here and have thereby provided a clearer insight into some of the mechanisms involved. However, it is noted that on several occasions, to progress matters smoothly, it has been necessary to introduce results that will only be fully developed in future papers. Recourse to future results in this fashion is frequently necessary in the development of complex, lengthy concepts. The results so used here will, in the next two papers, be adequately developed to fully justify such premature use. The first of these papers will cover the magnetic dipole coupling of electron orbit and spin to produce the fine structure splitting of the spectra.

One final, but significant point of a philosophical nature needs to be mentioned. Although the mechanical aspects of electron spin are not involved in producing the spectral signature, it is believed to be one of the most important features of atomic structure. Without it there could be no electron orbital transitions and consequently the nature of matter throughout the entire Cosmos, and all chemical and biological processes within it, would be very severely restricted. It is an astounding consequence that the nature of all things should be largely governed by the spinning of a simple elementary particle less than 6E-13 centimetres in diameter.

APPENDIX A.

Derivation of the Relativistic Angular Momentum of the Spinning Electron.

In the main text it was stated that for electrostatic reasons the electron was to be considered as a spinning spherical shell. Consequently it is necessary to determine the spin angular momentum of such a configuration and this is the subject of this Appendix. Consider Fig. A.1

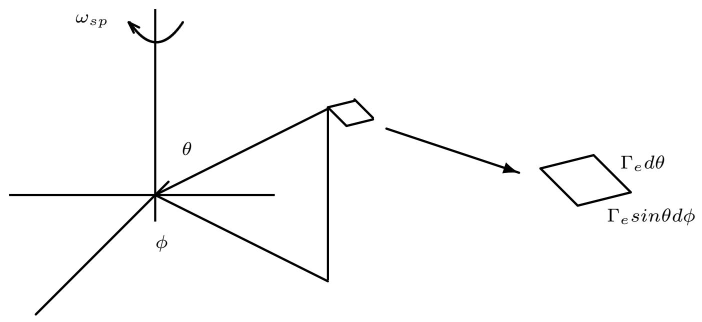

Fig.A.1 - A Spinning Electron Spherical Shell.

From Fig.A.1, the rest mass of the elemental is

$$\Delta m_0 = \delta m_0 \Gamma_e^2 \sin\theta d\theta d\phi \tag{A.1}$$

The velocity of the elemental is

$$v_e = \omega'_{sp}\Gamma_e \sin\theta \tag{A.2}$$

The energy mass of the elemental is therefore

$$\Delta m = \frac{\delta m_0 \Gamma_e^2 \sin\theta d\theta d\phi}{\left(1 - \frac{\omega'^2_{sp}\Gamma_e^2 \sin^2\theta}{c^2}\right)^{1/2}} \tag{A.3}$$

So that the relativistic angular momentum of the elemental is

$$\Delta M^*_{sp} = \frac{\delta m_0 \omega'_{sp} \Gamma_e^4 \sin^3\theta d\theta d\phi}{\left(1 - \frac{\omega'^2_{sp}\Gamma_e^2 \sin^2\theta}{c^2}\right)^{1/2}} \tag{A.4}$$

Taking a second order relativistic approximation

$$\Delta M^*_{sp} = \delta m_0 \omega'_{sp} \Gamma_e^4 \sin^3\theta \left(1 + \frac{\omega'^2_{sp}\Gamma_e^2 \sin^2\theta}{2c^2}\right) d\theta d\phi \tag{A.5}$$

Integrating over the surface of the sphere

$$M^*_{sp} = \delta m_0 \omega'_{sp} \Gamma_e^4 \int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} \left(\sin^3\theta + \frac{\omega'^2_{sp}\Gamma_e^2 \sin^5\theta}{2c^2}\right) d\theta d\phi \tag{A.6}$$

First with respect to ϕ gives

$$M^*_{sp} = 2\pi\delta m_0 \omega'_{sp} \Gamma_e^4 \int_{\theta=0}^{\pi} \left(\sin^3\theta + \frac{\omega'^2_{sp}\Gamma_e^2 \sin^5\theta}{2c^2}\right) d\theta \tag{A.7}$$

then with respect to θ to yield after minor reduction

$$M^*_{sp} = 2\pi\delta m_0 \omega'_{sp}\Gamma_e^4 \left(\frac{4}{3} + \frac{8}{15}\frac{\omega'^2_{sp}\Gamma_e^2}{c^2} + \cdots\right) \tag{A.8}$$

Taking an approximate binomial contraction this gives

$$M^*_{sp} = \frac{{}^2\!/_3 m_0 \omega'_{sp}\Gamma_e^2}{\left(1 - {}^4\!/_5 \frac{\omega'^2_{sp}\Gamma_e^2}{c^2}\right)^{1/2}} \tag{A.9}$$

When $\omega_{sp}\Gamma_e \to$ c this approximation gives about a 10% error. It is however, adequate for the purpose required in this paper.

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