ON KING'S CLASSICAL THEORY OF RADIATION

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1. *Introduction.*—In his paper, "Gyromagnetic Electrons and a Classical Theory of Atomic Structure and Radiation,"[1] Louis V. King endeavors to give a physical image of the quantum mechanism. Ever since quantum phenomena became definitely recognized many attempts were made to picture their mechanism.[2] In the case of King's theory there is an additional appeal to a scientific mind in the fact that his picture seems to unify the quantum phenomena with the classical electro-magnetic theory of Maxwell-Lorentz. Briefly stated the essentials of King's theory are as follows:

An electron is assumed to be a rigid sphere carrying a surface charge uniformly distributed and rigidly attached to the surface.

The electron is assumed spinning with constant intrinsic angular velocity Ω, the same for all electrons. The shape of the electron is assumed unchanged by rotation.

However, when the electron is given a velocity of translation, v, it is assumed to experience a Lorentz-Fitzgerald contraction in the direction of motion. The total electromagnetic energy of the deformed electron is then calculated. Allowing an amount $mc^2\alpha^2/4$ + constant for the work done by the boundary stresses of the electron, King arrives at the following expression for the entire energy of the deformed spinning electron moving with a uniform velocity, v.

$$T = mc^2 + {}^1/_2(Aw_1^2 + Bw_2^2 + Cw_3^2) + \text{constant}, \qquad (1)$$

where

c is the velocity of light;

$\alpha^2 = 1 - \beta^2 = 1 - v^2/c^2$;

w_1, w_2, w_3 are the components of the angular velocity in three mutually perpendicular directions, the first direction being chosen along v;

m is the mass of the moving electron assumed uninfluenced by rotation, i.e.,

$m = m_0/\alpha$, where m_0 is the rest mass;

A, B and C are the three principal moments of inertia, for which King obtains

$$A = ma^2(1-3\beta^2/5)/3(1-\beta^2) \qquad (2)$$

$$B = C = ma^2(1 + 4\beta^2/5)/3 \qquad (3)$$

where a is the radius of the electron before deformation.

On the basis of the above expression for the total energy King assumes that the electron moving with a constant velocity, v, behaves like a rigid body having moments of inertia A, B and C. Now, since the axis of spin in general does not coincide with any of the principal axes, he is led to the conclusion that the electron would precess.

Designating by h a quantity given by

$$h = 5\pi c^2 m_0/2\Omega, \tag{4}$$

using Euler's equations for rotation of rigid bodies, neglecting terms of the order of β^2 and higher, King finally obtains for the frequency of precession, ν, the relation

$$h\nu = \frac{1}{2} m_0 v^2. \tag{5}$$

King further assumes that when radiation impinges upon matter only those electrons are affected for which the precessional frequency, ν, is substantially equal to the frequency of the incident radiation, in which case the electron absorbs energy performing precession with increasing amplitude until it is finally ejected. In the process of ejection part of the energy of the electron P is spent in supplying the energy necessary for its removal, the remainder becoming the kinetic energy of the ejected electron, so that

$$\frac{1}{2} m_0 v^2 = P + \frac{1}{2} m_0 V^2, \tag{6}$$

V being the velocity of the ejected electron. By substituting from (6) into (5) one obtains the photo-electric formula

$$h\nu = P + \frac{1}{2} m_0 V, \tag{7}$$

where h is identified with Plank's constant.

The line spectra are explained in this theory by assuming that only those atoms are radiating in which the precessional angular velocity $2\pi\nu$ is related to the angular velocity in the orbit $n = v/r$ by the relation

$$2\pi\nu = sn. \qquad (s = 1, 2, 3, \ldots .). \tag{8}$$

On reading King's paper one is continually impressed by the ingeniousness of the theory, but, unfortunately, there are grave objections against it.

2. *Objections.*—If the electron is assumed to behave as a rigid body and acquire a precession, it could not absorb energy and maintain the frequency of precession. This can be seen by expressing the frequency in terms of the intrinsic spin.

Since two of the moments of inertia are equal, i.e., $B = C$, we can use the theory of symmetric tops.[3] The frequency of precession comes out equal to

$$\nu = \frac{1}{2\pi}\sqrt{2E/B - A\Omega^2/(B - A)} \tag{9}$$

where E is the total energy and the Ω intrinsic spin. If the intrinsic spin is assumed constant, as is done by King, the energy cannot change without a change of frequency of precession. Thus, photo-electric phenomena with monochromatic incident radiation would be impossible.

There is, however, another and much more important objection: We can easily show that a spinning electron moving with uniform translational velocity cannot have a precession at all. This is at once evident in Einstein's theory of relativity as the electron is not deformed to an observer moving with it; then, since it would not precess to this observer, it cannot precess at all.

However, King makes use of relativity only to the extent of the Lorentz-Fitzgerald contraction. Therefore, we obtain the same result by the following non-relativistic considerations. In fact, at some instant the angular momentum of the electron, as given by its three components, is

$$M = (Aw_1, Bw_2, Cw_3), \tag{10}$$

the components being taken in the three mutually perpendicular directions fixed in space. This can be done by choosing one of the axes along the axis of symmetry, which permanently coincides with the direction of the velocity, v. At some subsequent instant

$$M' = (A'w_1', B'w_2', C'w_3'). \tag{11}$$

Since it is assumed that there are no external forces

$$M = M'. \tag{12}$$

We must, therefore, have

$$Aw_1 = A'w_1', Bw_2 = B'w_2', \quad Cw_3 = C'w_3'. \tag{13}$$

Now, since our choice of axes is the same as in King's paper, the equations (2) and (3) show that A, B and C will remain unchanged, so that

$$A = A', \; B = B', \; C = C'. \tag{14}$$

When these are substituted into (13) we have

$$w_1 = w_1', \qquad w_2 = w_2', \qquad w_3 = w_3', \tag{15}$$

so that the three components of the angular velocity referred to the axes fixed in space remain unchanged, i.e., *there is no precession*. King derives a precession by using Euler's equations which are applicable to *rigid* bodies with the axes *fixed in the body*. The essential assumption in these equations is that the *principal axes of the body rotate with the body*, while in the case of a deformed electron moving in a straight line, the direction of the axis of symmetry is always that of the velocity, i.e., *fixed in space.* Thus, the electron does not behave as a rigid deformed sphere.

3. *Conclusion.*—We must, therefore, conclude that King's picture is incorrect. Moreover, it seems hardly desirable. In the modern theory the frequency of precession of the spinning electron (due to causes other than those discussed by King) has found its proper place. It accounts[4] for the normal doublets and triplets, that is, for a small change of the frequency and not for the whole effect.

[1] Mercury Press, Montreal, Canada.

[2] See, for instance, J. J. Thomson, *Phil. Mag.*, April, 1919.

[3] See, for instance, E. T. Whittaker, "Analytical Dynamics," VI, 69.

[4] See, for instance, Uhlenbeck and Goudsmit, *Naturwissenschaften*, **13** (1925), p. 953; *Nature*, **117** (1926), p. 264; *Physica*, **6** (1926), p. 273; Heisenberg and Jordan, *Z. Physik*, **37** (1926), p. 263.

ABSORPTION BANDS IN NITROGEN

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The excitation potentials of the nitrogen molecule have recently been determined by the electron impact method combined with spectroscopic observation.[1] In my previous measurements I had observed the excitation potential of the O-O band of the second positive group of nitrogen and I had calculated from these measurements and from the term scheme of R. T. Birge the corresponding potentials for the O-O bands of the first and fourth positive groups. Kneser had obtained the excitation potentials of the strongest bands of the first positive group. From these measurements the first excitation potential of the nitrogen molecule was given as 8.0 ± 0.3 volt. The band system corresponding to a transition from the energy level of 8.0 volts to the normal state is unknown and, therefore, a study of the absorption in nitrogen was carried out. The measurements have been made in the Department of Physics of the University of California, Berkeley, and as the time of my stay in Berkeley was limited, the investigation could not be finished and hence this report should be regarded only as preliminary.

The way in which the experiment was carried out is described in a paper being published in the *Zeitschrift für Physik.* I only want to mention that the final experiments were done with the new continuous light source for the extreme ultra-violet described by Lyman[2] and that the spectrograph