Letters to the Editor.

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On the generally accepted Explanation of the Zeeman Triplet on a Quantum Basis.

THE explanation of the simple Zeeman triplet on the basis of the quantum theory ostensibly depends on the application of Larmor's theorem.

This theorem may be expressed as follows:

Suppose a system of electrons describing orbits under the action of their mutual repulsions combined with any other forces the directions of which pass through an axis. Then if the system be subjected to the action of a uniform magnetic field H along that axis, the motion of the system is such that it may be represented as a possible motion with $H=0$ combined with a precessional rotation as a whole around the axis. When the other forces are central this applies to any direction of H as axis.

In the usual way of applying this theorem to the explanation of the Zeeman effect, the tacit assumption [1] is made that after the imposition of the magnetic field the rotating system is the *same* as before with simply the rotation superposed. This assumption is not only incorrect but would also seem open to two further objections, in that (1) the new orbit ceases to be quantised and (2) the total energy is supposed to be altered by the action of a magnetic field on a moving electron.

That the assumed new orbit ceases to be quantised is easily seen by considering a special case of, say, a circular orbit with its plane perpendicular to the magnetic force. The new path is assumed to be unchanged, but the velocity of the electron to be changed by the Larmor effect (which of course agrees with that calculated from the changed radial force Hev). The orbit therefore ceases to be quantised and the quantum law is disobeyed.

It would seem that the most natural way to attack the problem would be by first attempting a discussion of actual orbits. Unfortunately, however, this shows that no effect is to be expected—or if so the magnitude must depend on the square or higher powers of H. We can easily see this by the following considerations of simple cases.

1. Let us suppose the field is imposed by a very gradual increase from zero. The orbits of all electrons will gradually change. As the change is slow we have an adiabatic process and the new orbits will all remain quantised if the original were. But the magnetic field acts transversely on the moving electric charges, and the total energy will therefore remain unchanged. There is thus on the quantum theory no Zeeman effect.

2. Let us suppose the field already constituted and take the case of a circular orbit round a central force in a plane perpendicular to the field H. Then with the usual nomenclature

$$m\omega^2 r = \frac{e^2}{r^2} \pm He\omega r, \quad W = \tfrac{1}{2}m\omega^2 r^2 - \frac{e^2}{r}, \quad 2\pi m\omega r^2 = nh.$$

From the first

$$\frac{e^2}{r^2} = m\omega^2 r\left(1 \pm \frac{He}{m\omega}\right).$$

If we neglect squares of the small quantity $\pm He/m\omega (=x \text{ say})$ we may replace the ω in $He/m\omega$ by its value when $H=0$. Substituting for ω from the third we find

$$\frac{1}{r} = \frac{4\pi e^2 m}{n^2h^2(1-x)},$$

$$W = \frac{e^2}{r}\left(\frac{1}{2}\frac{1}{1-x} - 1\right) = \frac{4\pi^2 e^4 m}{n^2h^2(1-x)}\left\{\frac{1}{2}\frac{1}{1-x} - 1\right\}$$

$$= -\frac{2\pi^2 e^4 m}{n^2h^2}\frac{1-2x}{(1-x)^2} = -\frac{2\pi^2 e^4 m}{n^2h^2}$$

neglecting x^2 . . . But this is Bohr's value for no field. As this remains unchanged there is no Zeeman effect.

From the above considerations it would appear that the true explanation of the Zeeman effect on the quantum basis yet remains to be given. Doubtless it is to the nucleus that we must look for this. Should, for example, this contain structures analogous to permanent magnets a change of energy by an impressed magnetic force is possible. But it is not the object of the present note to go into this further question.

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[1] Larmor (see "Aether and Matter," p. 343), however, in stating his theorem expressly gives a warning against this assumption.

On the reported $K\beta_4$ Line in the X-ray Spectra of Molybdenum and Palladium.

IN a recent publication A. Leide (*Compt. rend.* 180, p. 1203 (1925)) has reported the results of an investigation of the wave-lengths in the K series of X-rays for elements having atomic numbers between 29 (copper) and 53 (iodine). The spectrograph used had a high resolving power so that the β_1 line was separated into its components. The accuracy was increased by a large number of exposures for each measurement. In addition to the well-known lines α_1, α_2, β_1, β_3 and γ or β_2, he has reported in the case of molybdenum (42) and palladium (46), a line β_4, ascribed to the transitions O_{II}, $O_{III} - K$.

Such transitions are permitted by the principles of selection, but transitions from O_I to K are prohibited. The schemes of electron distribution advanced at present (Bohr, Stoner) place no electrons in the O_{II}, O_{III} sub-levels in the normal states of the molybdenum and palladium atoms, but these elements lie in a portion of the periodic table where inner levels are presumably being filled up as electrons are added, admittedly making the actual electron distribution doubtful in the outermost levels. The presence of this β_4 line for these atoms would lead to the following alternatives: Either the O_{II} and O_{III} levels contain electrons before the first 18 electrons have entered the N shell, or we are here dealing with "semi-optical" X-ray lines, *i.e.* electron transfers from virtual orbits only occupied by electrons in atoms excited in the optical sense. Such orbits would presumably be greatly distorted in the atoms in a solid substance. Such semi-optical lines have been previously mentioned by Siegbahn and his co-workers (*Phil. Mag.* 49, 513 (1925)).

It has occurred to me that there may be some uncertainty as to the existence of this line in the K series spectra of molybdenum and palladium. Recently in this laboratory, in collaboration with Miss Alice Armstrong, a rather extensive reinvestigation of the molybdenum K series spectrum has been carried out, using an ionisation spectrometer. Some of the results of this work were reported to the American Physical Society at its spring (1925) meeting. In the course of the investigation no evidence was found for the presence of this β_4 line described by Leide, though readings were taken in that region of the spectrum in which it should occur. In this region, however, a discontinuity in the white or general radiation always appeared, due to the absorption by