quanta are allowed to traverse matter, and liberate electrons, and the energy of the liberated electrons is found to be h $(\nu-\nu')$. This is a case in which the whole energy of quantum is delivered to the electron, while in the case discussed here only a part just sufficient to liberate the electron is imparted. These are two extreme cases, and one is justified in assuming that the process is continuous, *i.e.*, a passing quantum can give to an electron inside an atom an amount of energy just equal to or greater than the amount required to liberate it, the excess appearing as the K. E. of the electron. The maximum K. E. should be $h\,(\nu-\nu')$ as observed by Robinson and others. But these authors did not examine the state of the quantum after it had traversed matter which was done by B. B. Ray. If the above view be correct the modified quanta should appear as a band with a sharp limit at $\nu-\nu'$ as observed by Ray, and extending to the long wave-length side indefinitely up to $\nu=0$. This band was actually observed by Bhargava and Mukherjee (*Nature, loc. cit.*). In spite of the fact that Ray's discovery is theoretically quite possible, and has been verified by other Indian workers, the reality of the effect was doubted, because many European and American workers were unable to reproduce it in the laboratory (*vide* para 2 of Chalklin's note). The following communication is important, because it is the first verification in a European laboratory, of not only the phenomena discovered by Ray, but also of the important feature of the case pointed out by Bhargava and Mukherjee. It is all the more important because in this experiment no crystal, which may give rise to false lines, but a grating was used. The failure of the other workers is to be attributed either to their use of large thicknesses of absorbing matter or to some other defect in their technique. It may also be pointed out that the phenomenon is extremely rare. Calculation with the data of one experiment has shown that only one quanta in 10^9 is modified by part-absorption on its passage through matter.

The Magnetic Moment of the Nucleus.

By Prof. B. Venkatesachar, M.A., F.Inst.P., *Central College, Bangalore.*

IN an attempt to explain the hyperfine structure exhibited by spectral lines Pauli introduced the hypothesis that the nucleus has a spin and consequently a magnetic moment. He also pointed out that investigations of the Zeeman effect of hyperfine structure would throw light on the magnetic properties of the nucleus. This hypothesis received full confirmation from the classical work of Back and Goudsmit on the hyperfine structure of Bismuth lines. The observed hyperfine structures conformed to the interval and intensity rules and the Zeeman effect was determined to be $4\frac{1}{2}\ h/2\pi$. Since this pioneer work the hyperfine structure of many elements has been investigated, and the spins of the corresponding nuclei have been deduced. In some cases the spin has also been calculated from the alternation of intensity in band spectra and the values found are small integral multiples of $\frac{1}{2}\ h/2\pi$. Now, the spin and the magnetic moment of the electron are related so that e/mc times the spin is equal to the magnetic moment. If a similar relation be supposed to hold in the case of the nucleus also, its magnetic moment should be expected to be of the order of 1/1835 of a Bohr magneton, since the mass of a proton is 1835 times that of the electron. It is found that the electrons in the nucleus must be supposed to have lost their spin in order to be able to understand the smallness of the $g(\mathrm{I})$ factors of nuclei. A knowledge of the $g(\mathrm{I})$ factor can be obtained in the following way:—

The fact that the interval rule is applicable to hyperfine structure separations is contained in the equation

$$W_{ij} = A\,(j)\; ij\cos\,(ij) \qquad \ldots\ldots\ldots\ldots (1)$$

Here $A(j)$ is the interval factor; a theoretical expression for it has been obtained by Fermi, Breit and Cassimir, as also by Goudsmit, in the case of a single valence electron, not of s-type. The expression is

$$A(j) = \frac{l(l+1)}{j(j+1)}\,a_{nl} \qquad \ldots\ldots\ldots\ldots (2)$$

where a_{nl} is the interaction constant of the valence electron. Its value can be calculated rigorously only by a quantum-mechanical treatment of the state under consideration. But for non-s-types of penetrating orbits it is approximately given in cm.$^{-1}$ by

$$a_{nl} = \frac{R\alpha^2 Z_i Z_0^2}{n_e^3\, l(l+1)(l+\frac{1}{2})}\,g(\mathrm{I}) \qquad \ldots\ldots (3)$$

Here Z_i and Z_o are the effective nuclear charges in the inner and outer parts of the orbit and n_e is the effective total quantum number. When there are more valence electrons than one the interval factor $A(j)$ can be expressed in terms of the interaction constants a_{nl} of the several electrons by making use of the method of energy sums as shown by Goudsmit (*Phys. Rev.*, **37**, 668, 1931). In this way one obtains for the 6s6d configuration the equations

$$\tfrac{1}{12} a_{6s} + 2\, a_{6d} = A(^3D_2) + A(^1D_2) \,..\, (4)$$
$$-\tfrac{1}{4} a_{6s} + 2\, a_{6d} = A(^3D_1) \ldots\ldots\ldots\ldots (5)$$

while for the 6s6p state one gets

$$\tfrac{1}{4} a_{6s} + \tfrac{2}{3} a_{6p} = A(^3P_2) \ldots\ldots\ldots\ldots (6)$$
$$\tfrac{1}{4} a_{6s} + 2\, a_{6p} = A(^3P_1) + A(^1P_1) \,..\, (7)$$

The 6s7s configuration yields the equation

$$\tfrac{1}{2}(a_{6s} + a_{7s}) = A(^3S_1) \ldots\ldots\ldots\ldots (8)$$

The propriety of applying these equations to any particular case can be tested by the consistency of the values of a_{6s} obtained from the various configurations. The g(I) factors of two nuclei can be compared by means of (3) when the values of a_{nl} are known in each case for the same value of n and l. Such a comparison is particularly instructive in the case of the two mercury isotopes Hg_{199} and Hg_{201} since here the two nuclei differ only by two protons and two electrons (*i.e.*, by two neutrons if the electrons are supposed not to have a separate existence).

The values of $A(^3D_2)$, etc., can be obtained from the analysis of Schüler and Jones (*Zs. f. Phys.*, **77**, 809, 1932). We have

$A(^3D_2) + A(^1D_2) = \frac{2}{5}(0{\cdot}752 - 0{\cdot}470) = 0{\cdot}113.$

$A(^3D_1) = -\frac{2}{3}(0{\cdot}493) = -0{\cdot}329.$

Hence from (4) & (5), $a_{6s} = 1{\cdot}326$ cm.$^{-1}$

$A(^3P_2) = (\frac{2}{5})(0{\cdot}758) = 0{\cdot}303;$

$A(^3P_1) + A(^1P_1) = \frac{2}{3}(0{\cdot}727 - 0{\cdot}181) = 0{\cdot}364.$

Hence from (6) and (7) $a_{6s} = 1{\cdot}150$.

The value of a_{6s} for Tl II, obtained from the same configurations are (see McLennan, McLay and Crawford, *Proc. Roy. Soc.*, **A 133**, pp. 657 and 663, 1931) 5·85 and 4·88 respectively. The ratio of the g(I) factors of Hg and Tl can now be calculated from (3). We thus obtain

$$\frac{g(I)_{Hg}}{g(I)_{Tl}} = \frac{(a_{6s})_{Hg}\,(n_e)^3_{Hg}\,(Z_i)_{Tl}\,(Z_o)^2_{Tl}}{(a_{6s})_{Tl}\,(n_e)^3_{Tl}\,(Z_i)_{Hg}\,(Z_o)^2_{Hg}}$$
$$= 0{\cdot}73 \text{ and } 0{\cdot}77 \text{ respectively.}$$

Thus the g(I) factors of Hg_{199} and Tl are of the same order. We can now calculate a_{6s} from (8) as follows: a_{7s} of Tl I $= 0{\cdot}417$ cm.$^{-1}$ n_e for $7s^2S_{\frac{1}{2}}$ of Tl I is 2·19; n_e for $6s7s^3S_1$ of Hg I is 2·24, while for $6s7s^1S_0$ of Hg I it is 2·32; hence n_e for Hg I 7s is 2·28. Z_i is 80 for Hg and 81 for Tl. Therefore from (3) a_{7s} of Hg I is 0·274. But since $A(^3S_1)$ of Hg_{199} is $\frac{2}{3}(1{\cdot}070) = 0{\cdot}713$, (8) yields $a_{6s} = 1{\cdot}152$. This value lies between the values 1·326 and 1·150 previously obtained; similarly, the corresponding value in Tl II, *viz.*, 5.40 lies between those obtained from the 6s6d and 6s6p configurations, *viz.*, 5·85 and 4·88. The consistency of these results shows that we are justified in applying the theory in the above manner.

A similar calculation in the case of Hg_{201} gives a_{6s} the value $-0{\cdot}495$ from the 6s6d configuration and $-0{\cdot}445$ from the 6s6p configuration. Thus the g(I) factor of Hg_{201} is 0·38 times (mean of 0·387 and 0·373 obtained from the two pairs of values) that of Hg_{199}. The problem is to draw conclusions about the structure of the nuclei from the knowledge of the ratio of their g(I) factors.

Following the discovery of the neutron, Heisenberg (*Zs. f. Phys.* **77**, 1, 1932) has shown that observed facts can be best explained by giving up the idea of the separate existence of electrons inside the nucleus, considering it to be made up of protons and neutrons alone. Remembering the great stability of α- particles we may assume that pairs of protons and neutrons are as far as possible combined into α- particles. When the atomic number is even there will be only α- particles and neutrons, while if Z is odd, there will be one extra proton. Since Hg_{199} and Hg_{201} differ only by two neutrons, the latter must be thought of as having orbital motion as well as spin, in order to understand the difference in their g(I) factors. Making this assumption, it has been shown (B. Venkatesachar and T. S. Subbaraya, *Cur. Sci.*, **1**, 120, 1932) that the neutron configuration of Hg_{199} is $4d^25s$. The g factor of the corresponding $^2S_{\frac{1}{2}}$ term is 2. The neutron configuration of Hg_{201} is $4d^35s^2$ and corresponding to the spin 3/2, the term may be $^2D_{3/2}$, $^4P_{3/2}$, or $^4F_{3/2}$. The g factor of Hg_{201} is therefore 4/5 or 26/11 or 2/5. The ratio of the g(I) factors of Hg_{201} and Hg_{199} deduced above may be understood if the state of Hg_{201} is assumed to correspond to $^2D_{3/2}$. The calculated value of the ratio of the g factors will then be 0·40 in good agreement with the value 0·38 found above.

Comparing Hg_{199} and Tl, the magnetic moment of Hg_{199} should be that of a neutron, while that of Tl is due to a proton. If now the neutron is thought of as a sphere of positive electricity imbedded in a sphere of negative electricity which is very much larger, the entire structure rotating with one angular velocity, and the moment of the whole being $\frac{1}{2}\, h/2\pi$, its magnetic moment will be of the same order as that of the proton, and the approximate equality of the $g(I)$ factors of Hg_{199} and Tl become intelligible.

Next considering Tl and Pb, the term corresponding to the spin $\frac{1}{2}$ in the case of Pb may be $^4D_{\frac{1}{2}}$ or $^4P_{\frac{1}{2}}$ or $^2P_{\frac{1}{2}}$, so that the g factor may be 0 or 8/3 or 2/3. If the term is taken to be $^2P_{\frac{1}{2}}$, the ratio of the g factors of Tl and Pb comes out to be (magnetic moment of the proton) / (one-third of magnetic moment of the neutron), that is 4, if the magnetic moment of the neutron is assumed to be 0·75 times that of the proton on the basis of our previous comparison of Hg_{199} and Tl. The value deduced by McLennan is between 3·7 and 5 (*loc. cit.* p. 666), thus agreeing with the theoretical value.

To interpret the ratio between the $g(I)$ factors of Tl and Bi deduced by McLennan (from 3·2 to 4·4; *loc. cit.*, p. 665) we have to consider the spin $4\frac{1}{2}$ of the Bi nucleus as due to a $^3G_5$ term with the spin of the proton oppositely directed. Then the magnetic moment of the Bi nucleus $= \frac{6}{5} \times 5 \times \frac{3}{4} - 1 = \frac{7}{2}$ so that its g factor $\frac{7}{2} \times \frac{2}{9} = \frac{7}{9}$. Hence the ratio of $g(I)_{Tl}$ to $g(I)_{Bi} = 18/7 = 2\cdot 6$. In this case the numerical agreement is not so good as before, but considering the uncertainties in the value deduced by McLennan, as also in the ratio between the magnetic moments of the proton and the neutron, exact numerical coincidence cannot be expected. Considerations of a similar nature may be expected to lead to an understanding of the extremely small value of the $g(I)$ factor in the case of elements like chlorine.

A Note on the Special Theory of Relativity.

By Prof. A. C. Banerji, M.A., M.SC., I.E.S., *Allahabad University.*

IT has been pointed out (*Current Science*, **1**, 160, 1932) that if there are two particles A and B of rest masses m_1 and m_2 (with respect to each other) moving with a relative velocity v, the total mass of the system can be calculated in two different ways. If m_1 be assumed to be at rest then the total mass of the system is found to be $m_1 + \frac{m_2}{\sqrt{1-\frac{v^2}{c^2}}}$ where c is the velocity of light. On the other hand, if m_2 is supposed to be at rest the total mass of the system becomes $m_2 + \frac{m_1}{\sqrt{1-\frac{v^2}{c^2}}}$. Clearly, these two expressions for the total mass are different.

In the first case the total energy of the system apart from the interaction energy (which, if any, will be the same in both the cases) is

$$m_1c^2 + \frac{m_2c^2}{\sqrt{1-\frac{v^2}{c^2}}}\,; \text{ i.e., } m_1c^2 + m_2c^2 + \tfrac{1}{2}\, m_2v^2$$

neglecting terms of higher order of small quantities. In the second case the total energy apart from the interaction energy would become $m_2c^2 + \frac{m_1c^2}{\sqrt{1-\frac{v^2}{c^2}}}$;

i.e., $m_2c^2 + m_1c^2 + \frac{1}{2}\, m_1v^2$

neglecting terms of higher order of small quantities. These two expressions for energy are different.

We also see that according to the observer A the total linear momentum of the system is $\frac{m_2v}{\sqrt{1-\frac{v^2}{c^2}}}$ and according to the observer B it is $\frac{-m_1v}{\sqrt{1-\frac{v^2}{c^2}}}$. These two expressions are evidently numerically different.

If there are two or more observers we can show more generally that the total energy of a system of particles becomes different when measured by different observers; and the law of conservation is not true in this sense, and the total energy is not an absolute property of the system. However, it is quite possible that for each particular observer the total energy may remain constant throughout the motion, but it is no new principle. The above remarks apply