LETTERS TO THE EDITOR

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Communications should not in general exceed 600 words in length.

Magnetic Moment of Li^7 in the α-Particle Model

The new method of Rabi[1] yields values of the nuclear magnetic moments of unprecedented accuracy. For Li^7, a moment of 3.265 ± 0.016 nuclear magnetons has been found[1] while preliminary measurements[2] of the proton moment gave 2.78 with an accuracy of about one percent. This gives a difference between the Li^7 and H^1 moments of 0.48, with a probable error of about ten percent. In contrast to this, existing theories based on the one-particle (Hartree) model[3, 4] give only 0.28 to 0.32 for this difference, a discrepancy of about 50 percent. It seems therefore worth while to re-examine the theoretical situation.

It seems almost certain that the total angular momentum of the Li^7 nucleus ($\frac{3}{2}$) is composed of a spin $\frac{1}{2}$ and an orbital momentum 1, and that the spin is due to the odd proton in the nucleus. These conclusions follow from the fact that pairs of like particles have a strong tendency to have resultant spin zero. There is considerable direct evidence for this tendency in that all nuclei with even numbers of neutrons and protons have zero spin. The tendency is also understandable theoretically because a strong repulsive force between like particles with parallel spins is required in order to give saturation of the nuclear forces, *i.e.*, to balance the attraction of like particles with opposite spin. Direct evidence for the repulsion of like particles in the triplet state may be found in the high mass of light nuclei of high isotopic number[5] such as Li^8 and B^{12}. In the particular case of Li^7, the four neutrons and two of the protons will give resultant spin zero, leaving only the spin of the third proton. Inglis[4] has shown by explicit calculation that there is only an extremely small probability for a state of affairs in which the two neutrons outside the alpha-particle have their spins parallel to the total spin and the proton opposite. Therefore, in first approximation, the magnetic moment of Li^7 should be equal to the proton moment plus the moment due to the orbital motion.

The calculation of the orbital magnetic moment requires a much more extensive use of a model than does the magnetic moment due to the spin. In the single particle model, it is assumed essentially that Li^7 consists of an α-particle core around which the three other particles are moving in a symmetric fashion. Thus the orbital momentum 1 will be shared about equally between the three particles, giving a momentum $\frac{1}{3}$ for the proton. Since the neutron orbital momentum contributes nothing to the magnetic moment, the orbital magnetic moment will be $\frac{1}{3}$, as pointed out by Inglis.[4] Only very small corrections have to be added to this figure which reduce it to about 0.30.

It may seem more satisfactory to consider the Li^7 nucleus as made up of an α-particle and a triton (H^3). This model seems more appropriate in our case than in many others because the binding energy of Li^7, as compared with He^4+H^3, is only 2.76 mMU (milli-mass-units) whereas the internal binding energies of H^3 and He^4 (as compared with free neutrons and protons) are 8.94 and 30.23 mMU, respectively. According to Teller,[6] it is plausible that the system of α-particle and triton must have an orbital momentum unity around its center of mass, in agreement with the experimental spin of Li^7 (see above).

With this model, the magnetic moment of Li^7 becomes equal to the intrinsic moment of the triton plus the orbital moment. The triton moment is certainly very close to the proton moment because the two neutrons in H^3 will have zero resultant spin (see above). The orbital angular momentum is shared between triton and α-particle in the inverse mass ratio. Since H^3 has a specific charge of $\frac{1}{3}$, He^4 one of $2/4$ times the proton specific charge, we find for the contribution of the orbital motion to the magnetic moment of Li^7

$$\mu_0=4/7\cdot 1/3+3/7\cdot 2/4=17/42=0.40_5.$$

This is in much better agreement with the observed value of 0.48 than the result of the single particle model, the difference being just within the experimental error. The reason for the improvement is that now the α-particle receives a share of the orbital momentum, and since its specific charge is greater than that of the triton, it gives a larger contribution to the magnetic moment. This may be considered as some evidence in favor of the α-particle model for lightly bound nuclei. For Li^6 which also falls in this class the model would predict exactly the deuteron moment.

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Ithaca, New York,
April 27, 1938.

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[1] Rabi, Zacharias, Millman and Kusch, Phys. Rev. **53**, 318, 495 (1938).
[2] Private communication from Professor Rabi.
[3] Rose and Bethe, Phys. Rev. **51**, 205, 993 (1937).
[4] Inglis, Phys. Rev., to appear shortly.
[5] Feenberg and Wigner, Phys. Rev. **51**, 95 (1937).
[6] Teller and Hafstad, Phys. Rev., to appear shortly.