If we take the expression given by Rarita and Schwinger[18] for the calculation of the neutron moment from the observed values of μ_P and μ_D,

$$\mu_n = \frac{\mu_D - \frac{3}{4}\times 0.039}{1-\frac{3}{2}\times 0.039} - \mu_P,$$

we obtain the value -1.911 ± 0.001 for μ_n, wherein the precision measure includes only experimental errors in the determination of μ_P and μ_D. These results are to be compared with the value of 1.935 ± 0.02 obtained by Alvarez and Bloch[4] for the magnetic moment of the free neutron. The uncertainty in the latter experiment is thus too great to yield an experimental check on the theoretical predictions. It is highly desirable that the moment of the free neutron be measured with a precision comparable to that obtained for the difference $\mu_D - \mu_P$.

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[18] W. Rarita and J. Schwinger, Phys. Rev. **59**, 436 (1941).

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On Electronic *g* Factors for Alkali Atoms

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Possible theoretical deviations from $g_J=2$ for the ground state of the alkalis are investigated, and it is concluded that none is large enough to affect measurably the experimental results.

It is assumed by Millman and Kusch[1] that for the ground level of an alkali atom $g_J=2$ is good to the accuracy of the experiments. This value of the gyromagnetic ratio for the electronic system follows at once from the description of an alkali atom in terms of a single electron moving in the central static field of the nucleus and core electrons. The energy level scheme predicted on this model is generally satisfactory, but inverted or anomalously narrow doublets occur frequently in alkali spectra,[2] indicating that the simple picture is not always justified. In view of this the question of possible perturbations of the magnetic moment must be considered seriously when high experimental accuracy is involved.

The anomalous doublet separations are adequately explained by taking into account the excitation of core electrons.[3] Possible dependence of the magnetic moment of the ground state on core excitation is here investigated. Two other aspects of the atom which are neglected in first approximation, the motion of the nucleus and relativistic effects, are also considered.

It can be easily shown that departures of the core from rigidity do not affect the mean value of the magnetic moment operator $(e/2mc)(L_z+2S_z)$ in this case. Such an effect would arise only if the ground state were not pure $^2S_{\frac{1}{2}}$ but contained some admixture of other $J=\frac{1}{2}$ states with different L or S. Perturbations due to excited levels may be found by writing the normal state wave function as $\Psi=\psi_0+\sum_i[V_{0i}/(E_0-E_i)]\psi_i$. Here ψ_0 is the approximate function for the lowest configuration, ψ_i that for some excited state i, and V_{0i} is the interconfiguration matrix element of the perturbing energy. The possible interacting configurations must be even, and the lowest of these would differ from the ground state only in that one of the core electrons has its total quantum number increased by unity. (No even states characterized by one-half unit of total angular momentum arise from excitation of the valence electron except for higher $^2S_{\frac{1}{2}}$

[1] S. Millman and P. Kusch, Phys. Rev. **60**, 91 (1941).
[2] Bowen and Millikan, Phys. Rev. **25**, 301 (1925).
[3] M. Phillips, Phys. Rev. **44**, 644 (1933).

levels.) It remains to consider the various possibilities for V_{0i}.

Electrostatic polarization of the core cannot be responsible for mixing into the ground state excited levels with $L\neq 0$ and $S\neq\frac{1}{2}$, since the electrostatic interaction commutes with the orbital and spin angular momenta separately, and hence will have no matrix elements non-diagonal with respect to L and S. Neither will the ordinary vector couplings, $\mathbf{l}_1\cdot\mathbf{s}_2$, $\mathbf{s}_1\cdot\mathbf{s}_2$, $\mathbf{l}_1\cdot\mathbf{l}_2$. Even the spin-orbit-spin interaction,[4] which in general has mean values non-diagonal in the total spin, does not perturb ^2S states, since the J value for a quartet S level is $\frac{3}{2}$. It follows that although there may be some mixture of excited configurations in the ground state the g_J factor is essentially unperturbed.

If the wave equation for the entire atom, including the nucleus, is used to determine the dependence of the energy E on a weak magnetic field H and dE/dH is then computed there is a small term due to the motion of the nucleus. This term is of the form $(e/2mc)(2m/M)[y_ip_{x_j}+y_jp_{x_i}-x_ip_{y_j}-x_jp_{y_i}]$, and is analogous to the Hughes-Eckart term which describes the specific isotope effect.[5] There will be non-vanishing matrix elements if i refers to the s electron and j to a p shell electron of parallel spin, but since both the s orbit and the closed p shell are spherically symmetric there will be no net contribution to the magnetic moment of the ground state. (The quantity in brackets has so small a mean value, besides having as a coefficient the ratio of the electron mass to that of the nucleus, that the estimated effect on the g factor for a P state of sodium is of the order 10^{-6}.)

Relativistic corrections have already been treated by Margenau.[6] For a $^2S_{\frac{1}{2}}$ level his formula reduces to $g_J=2(1-\frac{1}{3}v^2/c^2)$. This correction term is roughly the same for Na, Rb and Cs, and amounts to about 10^{-5}. This is too small to affect the measurements of Millman and Kusch.[1]

[4] E.g. H. A. Bethe, *Handbuch der Physik* Vol. XXIV, 1, 380.

[5] D. S. Hughes and C. Eckart, Phys. Rev. **36**, 69, 694 (1930).

[6] H. Margenau, Phys. Rev. **57**, 383 (1940).

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The Thundercloud as a Source of Penetrating Particles

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The paper describes cloud-chamber experiments designed to test the hypothesis that the electrostatic fields in thunderclouds can produce showers of electrons with energies as great as those found in the penetrating radiation. Sixty-five thunderstorms were observed and five thousand photographs of electron tracks were taken, together with four thousand five hundred control photographs. A statistical examination of the relative number of penetrating electron tracks seen in the two sets of photographs indicates that there is a very strong possibility that penetrating electrons *are* ejected from thunderclouds and reach the earth at considerable distances from the clouds. Evidence is thus obtained that storm clouds act as a source of penetrating electrons, but it is not known whether they are the only source. The experiments indicated that the simple hypothesis, that the penetrating electrons, after their ejection from the storm clouds travel in helical paths about the earth's magnetic field, is untenable.

Introduction

In 1925 and again in 1929, C. T. R. Wilson suggested that it was possible for thunderclouds, by reason of their very high potentials, to produce a shower of high speed electrons, with energies as high as 5×10^9 electron volts.[1,2] As the polarity of thunderclouds is predominantly positive (the positive charge being above the

[1] C. T. R. Wilson, Proc. Camb. Phil. Soc. **22**, 534 (1925).

[2] C. T. R. Wilson, J. Frank. Inst. **208**, 1 (1929).