which depend upon the size and the shape of the container, but in the limit of large volume, the results obtained for Landau diamagnetism and the Haas-van Alphen effect agree with those obtained by many previous authors. This last result should not appear to be surprising. One of these authors,[1] however, criticizes the procedure in previous calculations of ignoring the contributions of surface electrons to the partition function, on the grounds that completely different results could be obtained by methods which one has no *a priori* reason for rejecting. More specifically, reference is made to the discrepancy between the results obtained by making the approximation of neglecting surface states before or after differentiating the partition function with respect to the magnetic field. This discrepancy has been discussed by Teller[3] and Van Vleck,[4] who concluded that while the contribution of the surface states to the partition function is negligible in the limit of large volume, the direct contribution of these electrons to the magnetic moment must be included if the procedure is followed of summing over states after differentiating the partition function. Osborne rejects this explanation by pointing out that Van Vleck omitted certain states, and by stating that if these states are included, completely unreasonable results are obtained. It is the purpose of this letter to indicate that a consistent inclusion of effects, of the order of those contributed by the omitted states referred to, leaves the results of Van Vleck unaltered.

Van Vleck considers the electrons to be enclosed in a container of cylindrical shape, the axis of the cylinder being parallel to the magnetic field. The inner electrons are treated as being completely free, and the Schrödinger equation for the motion of a free electron in a plane perpendicular to the magnetic field is solved in polar coordinates, with the result that the energy levels are given by

$$W=(n_1+|n_1|+2n_2+1)h\nu, \tag{1}$$

where n_1 is the azimuth quantum number, n_2 the radial quantum number, and ν the Larmor frequency. The partition function is taken to be

$$Z=\sum_{n_1}\sum_{n_2=0}^{\infty}{}' \exp[-(n_1+|n_1|+2n_2+1)h\nu/kT], \tag{2}$$

where n_1 is to be summed over only those values of n_1 corresponding to inner electrons. Van Vleck takes the lower limit on this summation to be $n_1=-\pi eHR^2/hc$, R being the radius of the container; this value for the limit is obtained by considering the semiclassical equation

$$n_1=\pi eH(r^2-d^2)/hc \tag{3}$$

(r being the radius of the circular orbit and d the distance of its center from the origin) and by ruling out values of n_1 which would give $d>R$, on the assumption that $R\gg r$. The upper limit is taken to be $n_1=-1$, since, if $R\gg r$, only a negligible number of orbits encircle the origin (have positive n_1). It is this last assumption to which objection has been raised by Osborne. It is true that the sum in (2) includes many states for which the assumption $R\gg r$ is not valid, and hence states of positive n_1 should be included. For these states, however, the r^2 term in Eq. (3) cannot be ignored, and it is easy to see that the consistent inclusion of states of positive n_1, i.e., the correction of both the upper and lower limits on n_1, leads to results identical with those given by Van Vleck. If one introduces the principal quantum number $n=(n_1+|n_1|+2n_2)/2$, Eq. (1) becomes

$$W=(2n+1)h\nu, \tag{4}$$

and (2) becomes

$$Z=\sum_{n=0}^{\infty}\sum_{n_1}\exp[-(2n+1)h\nu/kT]. \tag{5}$$

It is clear that the upper limit on n_1 should be taken to be n. However, since the classical radius of the orbit is given by

$$r^2=hcn/\pi eH, \tag{6}$$

Eq. (3) can be written as

$$n_1=n-\pi eHd^2/hc, \tag{7}$$

and Van Vleck's criterion gives for the lower limit $n_1=n-\pi eHR^2/hc$. Thus, the correction of both the limits leads to all the results given by Van Vleck. It is thus seen that the inclusion of the orbits which enclose the origin does not lead to unreasonable results.

[1] M. F. M. Osborne, Phys. Rev. 88, 438 (1952).
[2] M. C. Steele, Phys. Rev. 88, 451 (1952).
[3] E. Teller, Z. Physik 67, 311 (1931).
[4] J. H. Van Vleck, *The Theory of Electric and Magnetic Susceptibilities* (Oxford University Press, London, 1932), p. 353.

Activation Cross Sections Measured with Antimony-Beryllium Photoneutrons. II

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Additional measurements of activation cross sections using Sb−Be photoneutrons (energy≅25 kev) have been made using the technique described by Hummel and Hamermesh.[1]

Table I contains a list of these cross sections relative to Seren's[2] thermal cross section for the given element.

Table I. Natural atom cross sections for (Sb-Be).

Isotope $(A+1)$	Half-life	Natural atom cross section (millibarns)	Percent error
Co^{60}	10.7 min	7.7[a]	30
Cu^{64}	12.8 hr	85	25
Ge^{75}	82 min	14	10
Ba^{139}	85 min	53	10
W^{187}	24.1 hr	119	15

[a] This value is an upper limit. The very small number of counts above background made it difficult to obtain good half-life values. The value in the table is obtained by assigning to the 10.7-min activity all counts above background corresponding to a half-life of less than thirty minutes.

[1] V. Hummel and B. Hamermesh, Phys. Rev. 82, 67 (1951).
[2] Seren, Friedlander, and Turkel, Phys. Rev. 72, 888 (1947).

Influence of the Nuclear Quadrupole Moment on the $\alpha-\gamma$ Angular Correlation in Radiothorium

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It is well known that the angular correlation between two nuclear radiations can be affected by magnetic fields, either atomic or applied, acting on the magnetic moment of the nucleus in its intermediate state. No attention seems to have been paid so far, in this connection, to the quadrupole moment of the nucleus. The influence of the quadrupole coupling on the angular correlations and the possibility of using this effect to measure the quadrupole moments of short-lived isomers are discussed in detail in a forthcoming paper by Abragam, Bloembergen, and Pound. The purpose of the present letter is to show that such coupling provides an explanation for the discrepancy between experimental and theoretical values of the $\alpha-\gamma$ correlation in the disintegration of radiothorium which has recently been investigated by two different groups.[1,2] Their results agree within experimental error.

The correlation is given in reference 1 as

$$W(\theta)=1+6.9\cos^2\theta-7.07\cos^4\theta,$$

or, if we rewrite it in terms of Legendre polynomials,

$$W(\theta)=1+0.30P_2-0.86P_4.$$

The theoretical correlation resulting from the most plausible disintegration scheme ($I_a=0$, quadrupole α-emission, $I_b=2$, quadrupole γ-emission, $I_c=0$) is $W=\cos^2\theta-\cos^4\theta$ or $1+(5/7)P_2-(12/7)P_4$. It is seen that the experimental correlation is weaker