solute values of the total L shell conversions obtained in various ways are given for the four $E2$ cases in Table II.

These results indicate that the agreement between experimental and theoretical L subshell conversion coefficients is very

TABLE II. L conversion coefficients of $E2$ transitions.

Converting nucleus	L conversion coefficient: Theory	$\frac{\alpha_K \text{ expt}}{(K/L)_{\text{expt}}}$	$\frac{\alpha_K \text{th}}{(K/L)_{\text{expt}}}$
Ta^{181}	0.72	0.80	0.82
Os^{186}	0.81	0.60	0.73
Hg^{198}	0.014	0.014	0.015
Hg^{199}	0.56	0.32	0.47

good, and until more complete computations are available, those already published by Gellman *et al.* may be used with considerable confidence for the identification of γ-transition multipolarities. A fuller account of these experiments will shortly be published elsewhere.

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† Fulbright Fellow. Permanent address: University of Western Australia, Perth, Australia.
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Nuclear Magnetic Resonance Modulation Correction

E. R. ANDREW
Department of Natural Philosophy, The University, St. Andrews, Fife, Scotland
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PERLMAN and Bloom[1] have recently drawn attention to an important correction for finite modulation amplitude which must be applied to measured nuclear magnetic resonance second moments if accurate structural information is to be deduced. By an approximate method they were able to show that the true second moment S_2 is related to the measured value S_2' by the relation

$$S_2' = S_2 + \tfrac{1}{3}h_m^2, \tag{1}$$

where h_m is the amplitude of the field modulation. Their approximation assumed that the modulation spreads the true absorption curve evenly over the range of modulation. The object of this note is to show that a direct calculation, without this approximation, leads to the same form of correction as Eq. (1), but that the coefficient of the last term is $\frac{1}{4}$ rather than $\frac{1}{3}$.

Suppose the true absorption line is described by a shape function $g(h)$, where $h=H-H_0$; H being the magnetic field and H_0 its value at the center of the line. The instantaneous signal voltage entering the "lock-in" amplifier is proportional to $g(h)$, and h will be given by

$$h = h_1 + h_m \sin(\omega_m t),$$

where h_1 is the mean value of h and $\omega_m/2\pi$ is the modulation frequency. Expanding $g(h)$ by Taylor's theorem, the instantaneous voltage is therefore proportional to

$$g(h_1) + \sum_{p=1}^{\infty} \frac{h_m{}^p \sin^p(\omega_m t)}{p!}\left[\frac{d^p g}{dh^p}\right]_{h_1}. \tag{2}$$

The lock-in amplifier gives a reading proportional to the coefficient of $\sin(\omega_m t)$ in the Fourier series in which Eq. (2) is expressible. This coefficient is found to be

$$f(h_1) = \sum_{q=0}^{\infty} \frac{h_m{}^{2q+1}}{2^{2q}q!(q+1)!}\left[\frac{d^{2q+1}g}{dh^{2q+1}}\right]_{h_1}, \tag{3}$$

where q takes integral values. For $q=0, 1, 2$ the numerical coefficients in Eq. (3) are 1, 1/8, 1/192 in agreement with Pake.[2]

The output of the lock-in amplifier is thus proportional to $f(h)$. The experimental value of the second moment is then obtained[3] as

$$S_2' = \int_{-\infty}^{\infty} h^3 f(h)dh \Big/ 3\int_{-\infty}^{\infty} hf(h)dh. \tag{4}$$

We now substitute for $f(h)$ from Eq. (3) and then integrate each term by parts. We assume that $g(h)$ and all its derivatives are zero at the limits of integration, and that they go to zero more rapidly than $1/h^3$. We are then left with only two terms in the numerator and one in the denominator, giving

$$S_2' = \left[\int_{-\infty}^{\infty} h^2 g(h)dh \Big/ \int_{-\infty}^{\infty} g(h)dh\right] + \tfrac{1}{4}h_m{}^2 = S_2 + \tfrac{1}{4}h_m{}^2, \tag{5}$$

which is the result stated above.

It has been found by experience in this laboratory that the range of modulation $2h_m$ may be set at about a quarter of the line width without introducing appreciable error. The line width, defined as the interval between maximum and minimum of the first derivative, is usually about twice the rms width (root second moment). From Eq. (5) it is seen that an error of about 2 percent is thus incurred in the second moment.

The preceding argument is readily extended to give the relation between the experimental $2n$th moment S_{2n}' and the true value S_{2n}:

$$S_{2n}' = \sum_{q=0}^{n} \frac{(2n)!h_m{}^{2q}}{2^{2q}q!(q+1)!(2n-2q)!} S_{2n-2q}.$$

Thus for the fourth moment ($n=2$),

$$S_4' = S_4 + \tfrac{3}{2}S_2 h_m{}^2 + \tfrac{1}{8}h_m{}^4.$$

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Effect of Capture on the Slowing-Down Length of Neutrons in Hydrogenous Mixtures

HOWARD C. VOLKIN
Lewis Flight Propulsion Laboratory, National Advisory Committee for Aeronautics, Cleveland, Ohio
(Received February 13, 1953)

A QUANTITY used in the problem of the slowing down of neutrons in a given material is the so-called slowing-down length, L_s, which is defined as follows: If a monoenergetic point source emits neutrons of energy E_0 in an infinite medium composed of the material in question, then the slowing-down length is given by $L_s^2(E, E_0) = \frac{1}{6}\langle r^2(E)\rangle_{\text{Av}}$, where $r(E)$ is the distance of a neutron of energy E from the source, the average being taken over all neutrons of this energy. Fermi[1] has derived a rigorous expression for this quantity for the case of hydrogenous media under the assumptions that the nonhydrogen nuclei have infinite mass and that capture is absent. The purpose of this communication is to present a generalization of Fermi's result which takes account of the presence of capture in the medium but still retains the assumption of infinite mass for the nonhydrogen nuclei. The resulting change in the magnitudes of L_s due to capture has been computed for a specific case.

Fermi's expression can be obtained from the appropriate transport equation.[2] When capture is taken into account the scattering term $f(\mu_0; u, u')$ in the transport equation becomes

$$f(\mu_0; u, u') = (1/2\pi)c(u')e^{-(u-u')}\delta[\mu_0 - e^{-\frac{1}{2}(u-u')}] + (1/4\pi)[1-c(u)-g(u)]\delta(u-u'), \tag{1}$$

where $u=\log(E_0/E)$ and $\mu_0 = \boldsymbol{\Omega}'\cdot\boldsymbol{\Omega}$, the unit vectors Ω' and Ω

specifying the neutron velocity direction before and after a scattering collision. The relative probability that a neutron in collision has its velocity parameters changed from the values Ω', u' before into the interval $d\Omega$, du about Ω, u afterwards, is given by $f(\mu_0; u, u')d\Omega du$. If the total, capture, and hydrogen scattering mean free paths are $l(u)$, $l_c(u)$, and $l_H(u)$, respectively, then $c(u)=l/l_H$ and $g(u)=l/l_c$. The quantity $-(1/4\pi)g(u)\delta(u-u')$ is the additional term due to capture. With the complete scattering function (1), the slowing-down length can be obtained by the same procedure used by Marshak in deriving Fermi's result, namely, differentiating the three integral equations which determine L_s and solving the resulting first order differential equations. The result is

$$L_s^2(u)=\frac{1}{3}\left\{\frac{l^2(0)}{[c(0)+g(0)]}+F(u)+\int_0^u du'\frac{c(u')}{c(u')+g(u')}F(u')\right\}, \quad (2)$$

where

$$F(u)=\frac{l^2(u)}{c(u)+g(u)}+l(0)l(u)\exp[-E(u)]$$
$$+l(u)\exp[-E(u)]\int_0^u du'\frac{l(u')c(u')}{c(u')+g(u')}\exp[E(u')],$$
$$E(u)=\int_0^u du'\left[\tfrac{3}{2}-c(u')-\frac{g(u')}{c(u')+g(u')}\right]. \quad (3)$$

It is evident for the following reasons that capture decreases the slowing-down length. Of the neutrons with any given energy, those farther from the source have traversed in general a greater path length. Thus the capture acts to reduce the ratio of the number of far-removed neutrons to the number of near ones, and hence to decrease the slowing-down length.

In the case of a boron oxide-water mixture (the ratio of hydrogen to boron nuclei chosen as 30), for a source energy of $E_0=10$ Mev, the value of L_s for thermal neutrons ($u\approx 20$) is decreased by about one percent if capture is taken into account. For a source energy of 3 kev, the value of L_s for thermal neutrons is decreased by about three percent. Capture by boron becomes appreciable only in the epi-thermal energy region, so that only for low energy sources does capture occur over enough of the energy range to affect the slowing-down length significantly. For elements with appreciable capture at higher energies the effect would be more important.

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The Decay of Mg^{28}

A. H. Wapstra and A. L. Veenendaal
Instituut voor Kernphysisch Onderzoek, Amsterdam, Holland
(Received May 8, 1953)

MAGNESIUM—28 is found to decay with a half-life of 21.4 ±0.6 hr (in agreement with former values 21.3±0.2 hr[1] and 21.2 hr[2]) to Al^{28}. The latter nuclide decays by an allowed β^- transition to the first excited state in the even-even nucleus Si^{28}, which is probably a 2^+ state; as the β^- transition to the Si^{28} ground state is forbidden, the ground state of Al^{28} is a 2^+ or 3^+ state.

We determined the maximum energy of the β^- particles of Mg^{28} from a Feather comparison of its absorption curve with that of Co^{60}; our value 0.39±0.05 Mev agrees with a former value 0.3–0.4 Mev.[2] With this value, log ft for this transition becomes 4.6±0.2, indicating an allowed transition. As Mg^{28} is expected to be in a 0^+ state, the level in Al^{28} reached by this transition is a 0^+ or 1^+ state; therefore this cannot be the ground state discussed above.

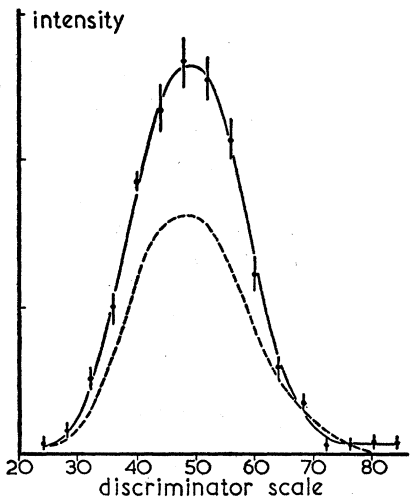

FIG. 1. Scintillation spectrum of Mg^{28} in equilibrium with Al^{28}. Dotted line: K x-ray line of Ba.

For this reason we looked for γ-rays. A scintillation spectrum, taken with a NaI(Tl) scintillation spectrometer built by Dr. N. F. Verster, revealed a low-energy γ-line, decaying with a 22-hr half-life, which almost coincided with the Ba K x-ray line (Fig. 1) in Cs^{137}; therefore its energy is 32.2 kev. This energy agrees with the excitation energy 31.4 kev of the first excited state in Al^{28}, found by analysis of d, p reactions on Al^{27}.[3]

After this work had been completed, this γ ray, together with others, was mentioned in a new paper by Sheline and Johnson.[4] However, they could not determine its intensity. For this purpose we compared the intensity of the 32-kev photopeak with the total intensity of the photopeak and Compton pulses of all higher energy γ-rays (the weakness of our sample did not allow us to investigate these γ-rays separately). Assuming the intensity ratios of these γ-rays as determined by Sheline and Johnson[4] and using the efficiency curves of Maeder and Wintersteiger[5] with a correction for the use of uncollimated bundles,[6] we find 0.7±0.2 32-kev γ rays per decay of Mg^{28}. This means that its conversion coefficient is less than 1, in agreement with the result of Smith and Anderson.[7] This value should be compared with the theoretical values 0.08 ($M1$), 0.22 ($E1$) 2.0 ($M2$), and 4.1 ($E2$) obtained by interpolation between the values of Rose *et al.*,[8] and those of Spinrad and Keller.[9] For all possibilities the ratio of K to $(L+M)$ conversion is high[10] (~6). The 32-kev γ ray can therefore only be an $E1$ or an $M1$ transition; shell theory considerations prefer an $M1$ assignment.

The Mg^{28} was prepared by an α, $2p$ reaction on Mg metal, using 56-Mev α-particles from the Philips synchrocyclotron in this institute. We thank Dr. C. J. Bakker and Dr. A. H. W. Aten, Jr., for their interest in this work, and the Foundation for Fundamental Research of Matter (F.O.M.) of the Netherlands Organization for Pure Scientific Research (Z.W.O.) for their support.

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