is about ±1 Mev at each point. The statistical errors in counting, as well as variations in relative activities as observed from day to day are small compared to effects of uncertainties in positions of samples during the irradiation.

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The Neutron-Electron Interactions

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FOLDY[1] has recently shown that the magnetic moment of the neutron can interact with the electrostatic field of an electron. This interaction is usually expressed as a uniform potential extending over a distance equal to the classical electron radius. If one chooses the neutron moment as −1.91 nuclear magnetons, the interaction is attractive, and its strength is 3900 ev. This surprisingly large value has its origin in the "zitterbewegung" of the magnetic moment of the neutron, which is assumed to be a Dirac particle. This effect does not constitute, however, the total neutron-electron interaction. There is another attractive potential whose physical origin stems from the fact that the neutron is sometimes a proton with a negative meson charge cloud surrounding it.

The two effects differ as follows: They arise from the interaction of the field of the electron with the neutron polarization current in the first case, and with the neutron convection current in the second. Each of these effects can be calculated from meson theory. Although they depend separately on the coupling constant, their ratio is independent of it.

This ratio has been calculated, assuming an interaction of the neutron with symmetric pseudoscalar mesons. Equations (5.10) and (6.11) of Borowitz and Kohn[2] have been used in conjunction with a meson mass of $282m_e$. The result is that $\delta j_{\mu p}\cdot A_\mu/\delta j_{\mu c}\cdot A_\mu$ is equal to 3.23; here $\delta j_{\mu p}$ and $\delta j_{\mu c}$ are the corrections to the neutron polarization and convection currents, respectively. If one fixes the coupling constant in order that the theory yield the phenomenological value for the neutron moment, the convection current contribution to the neutron-electron interaction is 1208 ev. The total interaction would thus be equal to 5108 ev. The Slotnick and Heitler[3] formulas give 5073 ev if one uses the same meson mass and fixes their coupling constant to give the correct value of the neutron moment. These results are in good agreement with previously reported values,[4,5] and with the one recently measured by Hughes,[6] 4200±700 ev.

This agreement, while interesting, is probably fortuitous for the following reasons: (1) The anomalous proton moment using the same coupling constant in the same theory would be about eight times too small. (2) It is unreasonable to suppose that a second-order perturbation calculation is correct, when the expansion parameter is so large.

Foldy's[1] conjecture that Slotnick and Heitler,[3] and Dancoff and Drell[7] have included both parts of the neutron-electron interaction in their results is thus supported. The discrepancy between their results and those of Case[8] and of Borowitz and Kohn[2] is largely resolved.[9]

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Energy Available for Double Beta-Decay of Sn^{124}†

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THERE has been considerable interest in the possibility that double beta-decay may occur with a measurable half-life. This interest has been heightened by Fireman's observation[1] of a half-life of $0.4\text{–}0.9\times10^{16}$ years for the Sn^{124}—Te^{124} transition. However, this observation has not been confirmed,[2–4] and studies of other potential double beta-emitters have yielded[5–7] negative results. Since the energy available for the decay is an essential datum for estimating the half-life, we have undertaken to measure this quantity with a mass spectrograph.

The Sn^{124}—Ni^{62} and Te^{124}—Ni^{62} doublets, photographed at mass number 62, yield the following mass differences: $\frac{1}{2}Sn^{124}-Ni^{62}=0.02378\pm12$ amu and $\frac{1}{2}Te^{124}-Ni^{62}=0.02297\pm19$ amu. The Sn^{124}—Te^{124} mass difference is, therefore, 0.00162±44 amu, or 1.5±0.4 Mev. This value, according to the experiments[2] of Kalkstein and Libby, gives a lower limit for the lifetime of the Sn^{124} double beta-decay of $2.1\pm0.3\times10^{17}$ years.

This measurement was in part undertaken at the suggestion of K. G. Standing. The authors wish to acknowledge a most helpful conversation on this general subject with W. F. Libby.

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Theory of Antiferromagnetic Resonance in a Crystal of Rhombic Symmetry at the Absolute Zero

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THE observed antiferromagnetic resonance phenomena in copper chloride, $CuCl_2\cdot2H_2O$, are only slightly dependent upon temperature at temperatures below about 3°K.[1] It appears to be possible to account for them on the basis of the analysis of antiferromagnetism in a crystal of rhombic symmetry at the absolute zero proposed by Gorter and Haantjes.[2]

We divide the lattice of magnetic ions into two sublattices i and j. An ion i is supposed to have a moment of momentum $(\hbar/2)\boldsymbol{\sigma}^i$ and a magnetic moment $(\mu_1\sigma_1{}^i,\ \mu_2\sigma_2{}^i,\ \mu_3\sigma_3{}^i)$. Let the exhange energy between two neighboring ions i and j be $\Sigma_k(\gamma_k/z)\sigma_k{}^i\sigma_k{}^j$ (z is the number of nearest neighbors).

Introducing $h_k=\mu_kH_k$ (**H** is the external field), Gorter and Haantjes, who follow the phenomenological treatment of Néel[3] and Van Vleck,[4] find at each value and direction of **h** three solutions for the magnetic moments which are mathematically permissible. They show which of these solutions will be realized physically. On this basis the resonance problem has been treated following the method used by Kittel[5] and Nagamiya.[6]

The equation of motion for the sublattice averages of the moments is

$$\alpha\bar{\sigma}_1{}^i/dt=(2/\hbar)[\bar{\sigma}_2{}^i(h_3-\gamma_3\bar{\sigma}_3{}^i)-\bar{\sigma}_3{}^i(h_2-\gamma_2\bar{\sigma}_2{}^i)]$$

(cyclic, and the same for i and j interchanged). Taking the variation of this equation and assuming the dependence upon time of the variations of the variables to be $\exp(i\omega t)$, one finds the resonance condition by putting equal to zero the determinant of the coefficients of the variations of $\bar{\sigma}_1{}^i$, $\bar{\sigma}_2{}^i$, $\bar{\sigma}_3{}^i$, $\bar{\sigma}_1{}^j$, $\bar{\sigma}_2{}^j$, $\bar{\sigma}_3{}^j$. To find the resonance condition in the form of a direct relation between **h** and ω one has to substitute the physically realized solution of Goerter and Haantjes into the equation which is obtained.

Supposing $\gamma_1>\gamma_2>\gamma_3$, we confine ourselves to two cases corresponding to those which have been investigated experimentally.

1. $h_2=0$. According to Gorter and Haantjes there is a threshold hyperbola $(h_1^2/c^2)-(h_3^2/a^2)-1=0$, where $a^2=\gamma_2^2-\gamma_3^2$, $c^2=\gamma_1^2-\gamma_2^2$ are supposed to be small with respect to γ^2. When **h** passes this curve, the moments jump from the X–Z-plane (solution I) to directions near the Y-axis (solution II). The resonance condition applied to solution II yields $h_1^2/(c^2+\nu^2)-h_3^2/(a^2-\nu^2)-1=0$ (where $\nu=\hbar\omega/2$), which is a hyperbola outside the threshold hyperbola (i.e., in the area which does not contain the center). The resonance condition applied to solution I yields a complicated equation, which for $\nu\to 0$ reduces to the threshold hyperbola and the points $h_1=\pm b=\pm(a^2+c^2)^{\frac{1}{2}}$, $h_3=0$. An approximation for small ν shows that the part which for $\nu\to 0$ coincides with the threshold hyperbola has moved inwards; the parts which for $\nu\to 0$ coincide with the points $h_1=\pm b$, $h_3=0$ have become closed curves in the neighborhood of these points. The latter curves, however, are irrelevant, since they lie in the region where solution I is not realized.

2. $h_3=0$. In this case the moments of the realized solution always have directions in the X–Y-plane. Applying the resonance condition yields again a complicated expression, which for $\nu\to 0$ reduces to the points $h_1=\pm c$, $h_2=0$. The approximation for small ν yields closed curves around these points, which, of course, intersect the h_1 axis in the same points as do the two curves found under 1.

All these results as well as the sign of the expected dispersion are in qualitative agreement with the observed phenomena. A fuller account and a quantitative comparison with the experiments will be published in *Physica*.

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Scintillation Response of Organic Crystals to Low Energy α-Particles

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THE scintillation responses of single flat crystals of anthracene, stilbene, and terphenyl to low energy α-particles have been studied, using a collimated Po^{210} source, and a 14-stage photomultiplier tube E.M.I. type 6262. The mean pulse size S, derived from the integral pulse distribution, was measured as a function of the mean residual air range r (at 15°C and standard pressure) of the α-particles incident on the crystal. Range corrections, which were small, were applied for the source thickness and for the slight divergence of the α-particle beam. The experimental response curve S *versus* r for stilbene is plotted in Fig. 1. Similar results were obtained for anthracene and terphenyl. It is found that for $r>$about 8 mm, S increases linearly with r, as observed previously by Birks,[1] but for $r<$about 8 mm the response S varies nonlinearly with r.

Birks[2,3] has formulated an exciton theory to account for the variation of the specific fluorescence dS/dr with the specific energy loss dE/dr of the exciting particle, leading to an expression

$$dS/dr=\frac{AdE/dr}{1+kBdE/dr}. \qquad (1)$$

The values for anthracene of $A=82.5$, $kB=7.15$ have been obtained experimentally. This theory accounts satisfactorily for the fluorescent response of organic crystals to electrons of energies >about 20 kev, to protons and deuterons>1 Mev (the minimum energy as yet investigated), and α-particles>about 1.6 Mev.[4]

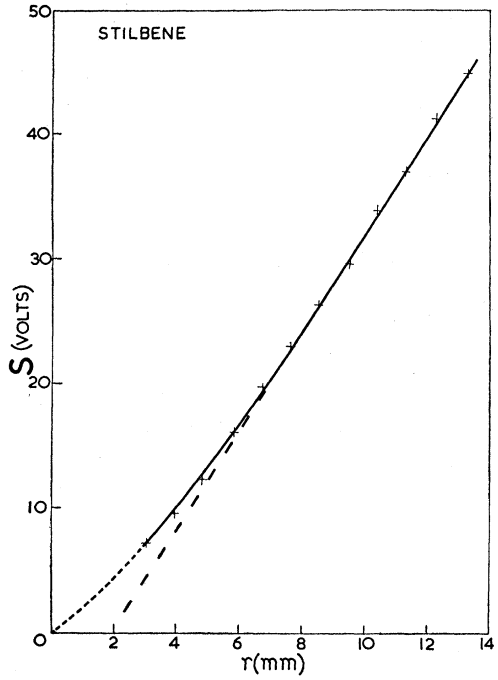

FIG. 1. Response of stilbene to α-particles of air-range r.

In particular, the theory indicates that for α-particles originating from Po^{210}, dS/dr is practically constant and independent of dE/dr. The experimental results in Fig. 1, and the similar curves for anthracene and terphenyl, show, however, that for $r<$about 8 mm, the value of dS/dr is less than that given theoretically by (1). The ratio ϕ of the experimental value of dS/dr from Fig. 1, to the theoretical value from (1), is plotted against r in Fig. 2. As r decreases from about 8 mm to zero, ϕ decreases from unity to 0.5. The value of r at which ϕ starts to decrease is approximately 8 mm for stilbene and terphenyl and 6 mm for anthracene. An extension of the exciton theory to account for this general effect has been formulated by Birks.[5]

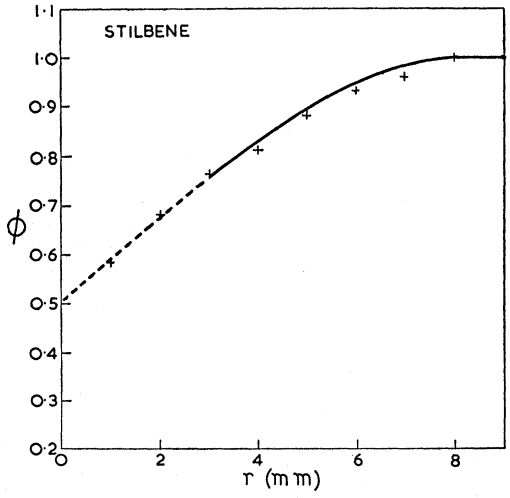

FIG. 2. ϕ [$=(dS/dr)$ experimental/(dS/dr) theoretical] *vs* α-particle air-range r.