ground state ($A = 0.0091$ cm^{-1} for Mn^{++} in $ZnSiF_6 \cdot 6H_2O$ lattice). For D, which is not known experimentally (and there being no obvious way to obtain it theoretically), we assume several values, namely, (a) -0.0134 cm^{-1} (i.e, that for Mn^{++}), (b) twice the value given in (a), (c) five times the value given in (a), (d) one-thousand times the value given in (a) [i.e., of the same order of magnitude as in ferrous fluorosilicate[7]], (e) one-fifth the value given in (a), and (f) one-tenth the value given in (a).

The results for the various cases of final Fe^{+++} configurations are presented in Table I. It is seen that Q_2 ranges anywhere from 0.25 to 0.53.[8] We will not make any attempt to calculate a final value of Q_2, which requires a knowledge of the branching ratios to the various end-state configurations, namely, Fe^{++}, Fe^{+++}, ... since these ratios are not at all known. However, it is clear from the results that a final value of $Q_2 = 0.32$ is possible.

We thus conclude that the model of I includes in its range the observed reorientation for the case of Co^{57} in a fluorosilicate lattice.

We are grateful to the National Research Council of Canada for financial support, to Dr. B. Frank for helpful comments on the manuscript, and to G. R. Sharp for assistance in processing the computer programs.

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[4] The spin Hamiltonian of the parent state is of the form $g_{\parallel}\mu_B H_z S_z + A S_z I_z + g_{\perp}\mu_B (H_x S_x + H_y S_y) + B(S_x I_x + S_y I_y)$, with $g_{\parallel} = 5.82$, $g_{\perp} = 3.44$, $A = 0.0184$ cm^{-1}, and $B = 0.0047$ cm^{-1} {i.e., those for Co^{59} in $ZnSiF_6 \cdot 6H_2O$ lattice at 20 °K [see K. D. Bowers and J. Owen, Rept. Progr. Phys. 18, 304 (1955)]; since the magnetic moments of Co^{57} and Co^{59} are almost the same, we have used the same values of A and B}.

[5] G. K. Wertheim, Phys. Rev. 124, 764 (1961).

[6] The Fe^{1+} and Fe^{4+} states are also observed in some oxide hosts, but the Fe^{2+} and Fe^{3+} states occur most commonly. See, e.g., W. Triftshäuser and D. Schroeer, Phys. Rev. 187, 491 (1969).

[7] R. S. Rubins and H. R. Fetterman, Bull. Am. Phys. Soc. 16, 522 (1971). Their measurements yield a spin Hamiltonian of the form $g_{\parallel}\mu_B H S_z + D S_z^2 + E(S_x^2 - S_y^2)$ in ferrous fluorosilicate with $S = 2$, $g_{\parallel} = 2$, $D = 11.8$ cm^{-1}, and $E = 0.54$ cm^{-1}.

[8] The nuclear alignment parameter is proportional to A_2. Then $Q_2 = A_2$ (average)$/A_2(0+)$. Because of increased decoupling between $\vec{S}$ and $\vec{I}$, as seen from the form of $\mathcal{H}_{\text{eff}}$, lesser reorientation is obtained for larger values of D.

PHYSICAL REVIEW B VOLUME 4, NUMBER 5 1 SEPTEMBER 1971

Comparison of Mass Absorption Coefficients of Positive and Negative Beta Particles in Aluminum and Tin

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(Received 1 March 1971)

Mass absorption coefficients for six negative and three positive β-particle sources have been determined for aluminum and tin absorbers. Most of the large difference in the μ/ρ values relevant to ^{86}Rb and ^{68}Ga reported for aluminum by Takhar is shown to be due to the difference in their end-point energies; however, a significant difference in μ/ρ values for tin remains.

Takhar[1] compared the transmission of positive β particles from ^{68}Ga (having the end-point energy $E_0 = 1.88$ MeV) with that of negative β particles from ^{86}Rb ($E_0 = 1.77$ MeV) in various substances and reported that the mass absorption coefficient μ/ρ for positive β particles is less than that for negative β particles by about 12% for aluminum, 19% for copper, 25% for tin, and 35% for lead. The aluminum results were in disagreement with the results of Chang *et al.*[2] and of Baskova and Gorbachev,[3] who observed no significant difference in the transmission through aluminum foils of monoenergetic positive and negative β particles. Commenting on the results of Takhar for aluminum, Cook[4] observed that the β-particle spectra of ^{68}Ga and ^{86}Rb are complex and not sufficiently similar to allow direct comparison of transmission through various foils of the positive and negative β particles. He also pointed out that if one accepts the energy-dependent formula of Gleason *et al.*[5] for

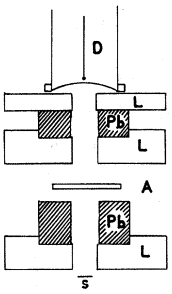

FIG. 1. Schematic diagram of the experimental arrangement. S, source; L, Lucite collimator; Pb, lead collimator; A, absorber; D, detector.

the mass absorption coefficients for positive as well as negative β particles, then 9% of the 12% difference observed by Takhar can be attributed to the difference in end-point energies of the two β-particle spectra. However, he expressed doubt as to the validity of the formula of Gleason *et al.*[5] for positive β particles. It is well known that the values of mass absorption coefficients for β particles are influenced by the geometry, and so it is desirable to determine the coefficients for both positive and negative β particles in the same geometry. In view of these points we have determined, adopting a good geometry arrangement which is suitable for positive as well as negative β particles, the mass absorption coefficients in aluminum and tin using six negative β-particle sources and three positive β-particle sources covering the end-point energy range from about 0.4 to 2.3 MeV.

In the geometry adopted by Gleason *et al.*[5] the absorbers are placed close to the detector, and so the background counts due to the annihilation photons produced in the absorber remain an appreciable fraction of the counts due to the transmitted positive β particles. This background varies as a function of thickness of the absorber. Such an arrangement is, therefore, not suitable for the determination of mass absorption coefficient of positive β particles. The experimental arrangement of the present investigations is shown in Fig. 1. A collimated beam of β particles is made to fall on a Geiger counter and the absorbers are placed midway between the source and the detector. The efficiency of the Geiger counter used is less than 0.5% for 0.5-MeV photons, and in this arrangement the probability that an annihilation photon produced in the absorber would lead to a background count is less than 5×10^{-5}. Thus we see that even when 99% of the positive β particles are stopped in the absorber, the background counts due to annihilation photons produced in the absorber would be less than 1% of the counts due to the transmitted positive β particles. Because of the small solid angle subtended by the effective area of the detector, the background counts resulting from the secondary electrons produced in the absorber, due to the γ rays and annihilation photons from the source, are also negligible. So in this arrangement, the variation in the background counts that depend on the thickness of the absorber remains negligible compared to the counts due to the transmitted positive β particles. Hence this arrangement is suitable for studying the transmission of positive β particles as a function of the absorber thickness.

Using this experimental arrangement we have measured the transmission of positive β particles from the sources ^{58}Co (0.474), ^{22}Na (0.544), and ^{68}Ga (1.88) and of negative β particles from the sources ^{185}W (0.43), ^{204}Tl (0.76), ^{91}Y (1.545), ^{32}P (1.697), ^{86}Rb (1.774), and ^{90}Y (2.284); the figures within the brackets indicate the end-point energies[6] in MeV. All the positron sources and ^{86}Rb emit γ rays also, and the measured transmission has been corrected for this background using the standard method. We find that for both positive and negative β particles the transmitted β-particle intensity decreases exponentially with the thickness of the absorber over different ranges of transmission for different β-particle sources and for different absorbers. However, for all the sources used it decreases exponentially in the transmission range from 20 to 1% in the case of aluminum and from 10 to 0.5% in the case of tin. Using the least-

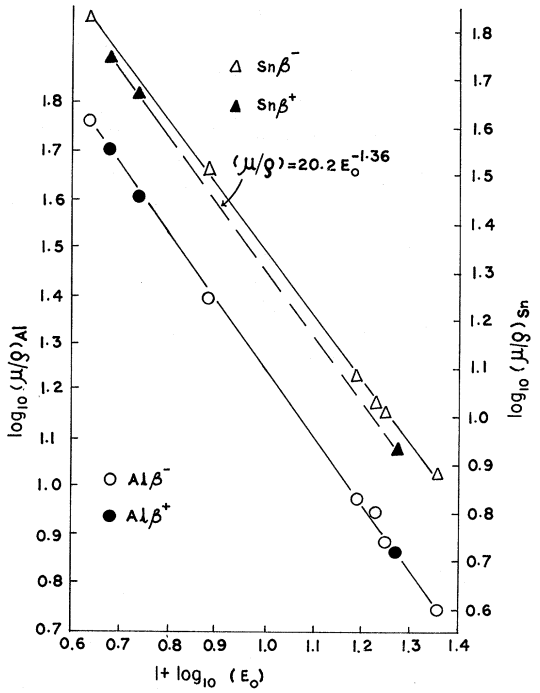

FIG. 2. Experimentally determined values of $\log_{10}\mu/\rho$ (cm^2g^{-1}) plotted as a function of $\log_{10}E_0$ (MeV). The solid lines are the least-squares straight-lines fits for negative β-particle sources.

TABLE I. Comparison of μ/ρ ($cm^2 g^{-1}$) values of positive and negative β particles for tin.

β-particle source	$(\mu/\rho)^+$ expt	$(\mu/\rho)^-$ calc	Deviation
^{58}Co	55.3	59.4	−7%
^{22}Na	46.7	49.4	−6%
^{68}Ga	8.53	9.5	−10%

squares-fit method, we have calculated the mass absorption coefficient for each β-particle source over these transmission ranges only; that is, only the most energetic portion of the β-particle spectra (near the end-point energy E_0) is employed in the determination of μ/ρ.

The mass absorption coefficient for negative β particles follows a law of the type[5]

$$\mu/\rho = AE_0^{-B}, \tag{1}$$

where A and B are constants. In order to facilitate comparison of μ/ρ values of the positive and negative β-particle spectra we have, in Fig. 2, plotted the experimentally determined values of the $\log_{10} \mu/\rho$ against $\log_{10} E_0$ for all β-particle sources used. The solid lines are the least-squares straight-lines fits for negative β-particle spectra.

We see that, in the case of aluminum, the experimental points corresponding to positive β-particle spectra lie close (within an experimental error of about 3%) to the least-squares straight-line fit of the negative β-particle spectra. This shows that the μ/ρ values for positive β-particle spectra also satisfy the equation $\mu/\rho = 17.6\, E_0^{-1.39}$ relevant to negative β-particle spectra, where μ/ρ is in units of $cm^2 g^{-1}$ and E_0 in MeV, and that there is no significant difference in the values of the mass absorption coefficients of aluminum for positive and negative β-particle spectra having the same end-point energy.

On the other hand, in the case of tin the experimentally determined μ/ρ values corresponding to the positive β-particle spectra lie lower than the least-squares straight-line fits relevant to negative β-particle spectra. This shows that the mass absorption coefficient corresponding to the positive β-particle spectrum is significantly smaller than that corresponding to the negative β-particle spectrum having the same end-point energy. In Table I we compare the experimentally determined μ/ρ values relevant to three positive β-particle sources with the calculated μ/ρ values using the least-squares-fit equation $\mu/\rho = 22\, E_0^{-1.33}$ $cm^2 g^{-1}$ of the negative β-particle spectra having the same end-point energy. We see from the last column that the difference increases with the end-point energy going from 6% at $E_0 = 0.544$ MeV to 10% at $E_0 = 1.88$ MeV. Takhar[1] reported a 25% difference for tin using ^{86}Rb and ^{68}Ga.

We may conclude that, if we assume that a formula of the type given by Gleason *et al.*[5] is applicable to both negative and positive β particles, the large difference observed by Takhar[1] in aluminum in the mass absorption coefficients of positive and negative β particles is essentially due to the difference in the end-point energies of the sources used, as rightly pointed out by Cook.[4] Part, but not all, of the difference for tin is also attributable to the difference in the end-point energies. We have not studied copper or lead.

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