Tensor Type ($\int B_{ij}$) Component in the 2.31-Mev β Transition of Sb^{124}†*

R. M. STEFFEN
Department of Physics, Purdue University, Lafayette, Indiana
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The β-γ directional correlation of the first-forbidden 2.31-Mev β transition of Sb^{124} and of the 0.603-Mev γ ray of Te^{124} was measured. The integral β-γ directional correlation measured at an average β energy, $\bar{W}=4.8$, is represented by $W_{\beta\gamma}(\theta,\bar{W}=4.8)=1-(0.390\pm0.011)P_2(\cos\theta)+(0.004\pm0.013)P_4(\cos\theta)$. The negligibly small $P_4(\cos\theta)$ term provides additional evidence against a second-forbidden β transition. The energy dependence of the anisotropy coefficient $A_2(W)$ in the correlation function $W_{\beta\gamma}(\theta,W)=1+A_2(W)\times P_2(\cos\theta)$ was measured. The experimental values of $A_2(W)$ exclude the possibility of a pure $\int B_{ij}$ transition, but give conclusive evidence that the $\int B_{ij}$ matrix element contributes very significantly to the 2.31-Mev β transition of Sb^{124}. In fact, the directional correlation data are well represented, if $C_A\int B_{ij}\cong -C_V\int i\boldsymbol{\alpha}+\xi C_V\int \mathbf{r}-\xi C_A\int i\boldsymbol{\sigma}\times\mathbf{r}$, where $\xi=Z\alpha/2R$.

1. INTRODUCTION

IT has recently become of interest to study the relative contributions of the various matrix elements to nonunique first-forbidden β transitions. The determination of individual matrix elements, however, is only possible if the β transition displays a deviation from the ξ approximation.[1,2] If the β transition is well described by the ξ approximation, only linear combinations of the matrix elements of the same tensor rank can be extracted from shape and angular correlation measurements with limited accuracy (of the order of 1%).[3] The determination of individual matrix elements would require a very high degree of accuracy. This is hardly feasible with present day experimental techniques.

Deviations from the ξ approximation, however, may occur if the tensor-type matrix element $\int B_{ij}$, whose contribution is neglected in the ξ approximation, can no longer be disregarded. Two reasons may be responsible for the relative enhancement of the $\int B_{ij}$ contribution, which corresponds to two units of angular momentum carried away by the lepton field.

Selection rules (e.g., j selection rules, K selection rules) may inhibit the lepton field components which carry away one or zero units of angular momentum. In other words, the "normal" vector-type ($\lambda=1$) and scalar-type ($\lambda=0$) matrix elements may be greatly reduced, whereas the tensor-type matrix element $\int B_{ij}$ may be little or not at all affected by selection rules.

In fact, the parity change between the initial and final nuclear states involved in a first-forbidden β transition leads to an angular momentum difference between the nucleon orbitals of $\Delta j\geqslant 2$, if the transition involves shell-model configurations whose nucleon orbitals belong to the same major shell. This situation was pointed out by King and Peaslee.[4] Consequently all matrix elements with tensor rank $\lambda<2$ should vanish if the j selection rules were strictly observed, i.e., if no admixtures from other major shells were present.

A second reason for the predominance of the $\int B_{ij}$ component may be the mutual cancellation of the lower tensor rank ($\lambda<2$) matrix elements.

Both the selection rules and cancellation effects lead to ft values of the β transitions which are considerably larger than the regular ft values ($\log ft\approx 7$) of first-forbidden nonunique transition.

Several experimental facts indicate that the "normal" vector-type matrix elements ($\int i\boldsymbol{\alpha}$, $\int\mathbf{r}$, $\int i\boldsymbol{\sigma}\times\mathbf{r}$) involved in the 2.31-Mev β transition of Sb^{124} (Fig. 1), which leads from the 3^- level of Sb^{124} to the first-excited 2^+ state of Te^{124}, may be reduced, and consequently the $\int B_{ij}$ component may predominate in the transition. The ft value of the β transition is larger than usual, $ft=10^{10.6}$ sec. The shape of the β spectrum shows considerable deviations from the statistical shape,[5] the shape expected if the ξ approximation were applicable.[3] A preliminary measurement of the β-γ directional correlation indicated a large β-γ anisotropy.[6]

Thus a careful investigation of the β-energy depend-

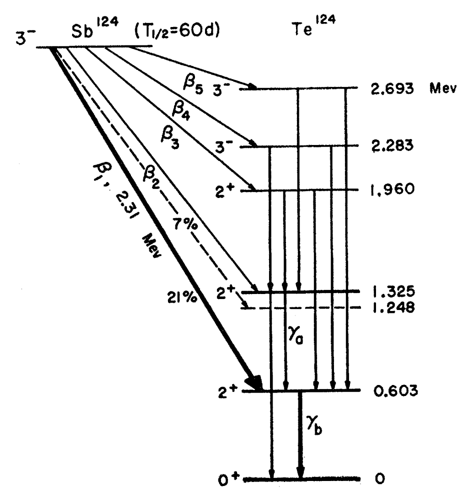

FIG. 1. Decay of 60-day Sb^{124}.

† A preliminary report of this work was published in Phys. Rev. Letters 4, 290 (1960).
* Supported in part by the U. S. Atomic Energy Commission.
[1] T. Kotani, Phys. Rev. 114, 795 (1959).
[2] R. M. Steffen, Phys. Rev. 123, 1787 (1961).
[3] T. Kotani and M. Ross, Phys. Rev. 113, 622 (1959).
[4] R. W. King and D. C. Peaslee, Phys. Rev. 94, 1284 (1954).
[5] L. M. Langer and D. R. Smith, Phys. Rev. 119, 1308 (1960).
[6] D. T. Stevenson and M. Deutsch, Phys. Rev. 83, 676 (1951).

ence of the Sb^{124} β-γ directional correlation seemed to provide a means to determine the extent of the $\int B_{ij}$ contribution, and it was hoped that the individual matrix elements contributing to the 2.31-Mev β transition might be determined. The present paper describes the directional correlation measurements on the $3^-(\beta, 2.31 \text{ Mev}) \rightarrow 2^+(\gamma, 0.603 \text{ Mev}) \rightarrow 0^+$ cascade of Sb^{124}.

2. THEORY OF β-γ DIRECTIONAL CORRELATIONS

The directional correlation between a beta particle and a successively emitted γ ray is given by

$$W_{\beta\gamma}(\theta)=1+\sum_{k=1}^{k_{\max}} A_{2k}P_{2k}(\cos\theta). \qquad (1)$$

The coefficients A_{2k} may be written as a product of two factors $A_{2k}{}^{\beta}(W)$ and $A_{2k}{}^{\gamma}$ which depend on the parameters describing the β transition and γ transition, respectively[7]:

$$A_{2k}=A_{2k}{}^{\beta}(W)A_{2k}{}^{\gamma}. \qquad (2)$$

The factor $A_{2k}{}^{\gamma}$ is characteristic of the γ transition involved in the $I_0(\beta)I_1(\gamma)I_2$ β-γ cascade between nuclear levels of angular momentum I_0, I_1, and I_2. If the γ-transition is a mixture of multipole components of multipole character L and L', $A_{2k}{}^{\gamma}$ is given by

$$A_{2k}{}^{\gamma}=\frac{F_{2k}(LLI_2I_1)+2\delta F_{2k}(LL'I_2I_1)+\delta^2F_{2k}(L'L'I_2I_1)}{1+\delta^2}, \qquad (3)$$

where δ is the ratio (mixing ratio), $\delta=(I_1\|L'\|I_2)/(I_1\|L\|I_2)$, of the reduced γ-matrix elements. The F coefficients, $F_{2k}(L_1L_2I_1I_2)$, are tabulated in reference 8. A pure γ transition of multipolarity L is characterized by

$$A_{2k}{}^{\gamma}=F_{2k}(LLI_2I_1). \qquad (4)$$

The factor $A_{2k}{}^{\beta}(W)$ is a function of the β energy W. The maximum value of the index k is equal to the degree of forbiddenness of the β transition if higher order effects [e.g., Gell-Mann terms, cross terms of n and $(n+2)$ forbidden components] are neglected. Consequently, β-γ directional correlations involving first-forbidden β transitions are of the form:

$$W_{\beta\gamma}(\theta)=1+A_2{}^{\beta}(W)A_2{}^{\gamma}P_2(\cos\theta). \qquad (5)$$

The presence of a nonvanishing $P_4(\cos\theta)$ term ($|A_4|>0.03$) in an experimental β-γ directional correlation is a strong indication of a second- or higher-order forbidden β transition.

A first-forbidden beta transition for which the ξ approximation is valid displays a β-γ directional correlation whose $A_2{}^{\beta}(W)$ coefficient has the following β-energy dependence:

$$A_2{}^{\beta}(W)=\lambda_2(Z,W)\frac{p^2}{W}M(I_0I_1), \qquad (6)$$

where $p=(W^2-1)^{\frac{1}{2}}$ is the momentum of the β particles. Values of the factor $\lambda_2(Z,W)$ are tabulated in reference 3. $\lambda_2(Z,W)$ is of order unity and almost independent of the β energy for $W>2$. The factor $M(I_0I_1)$ is independent of W and depends on linear combinations of the nuclear matrix elements contributing to the β transition and on the angular momentum quantum numbers I_0 and I_1 of the nuclear states involved.[2] Thus, if the ξ approximation is valid the experimental quantity $A_{2,\exp}[\lambda_2(Z,W)p^2/W]^{-1}$ has a constant value.

If the ξ approximation breaks down due to a dominant contribution of the tensor-type matrix element $\int B_{ij}$, the β-γ anisotropy coefficient $A_2(W)$ has a more complicated energy dependence than given in Eq. (6). If the matrix element $\int B_{ij}$ is considerably larger than any other matrix element contributing to the first-forbidden β transition, the so-called "modified B_{ij}" approximation, which was introduced by Matumoto *et al.*[9] may be used. The β-γ anisotropy factor $A_2(W)$ for a $3^-(\beta)2^+(\gamma, L=2)0^+$ β-γ cascade is, in this approximation, given by

$$A_2(W)=A_2{}^{\beta}(W)F_2(2202)$$
$$=\frac{-p^2}{7W}\frac{12\lambda_2Yz+2\lambda_1Wz^2}{12Y^2+[\lambda_1p^2+(W_0-W)^2]z^2}. \qquad (7)$$

The parameter Y is a linear combination of the nuclear matrix elements $\int i\boldsymbol{\alpha}$, $\int \mathbf{r}$, and $\int i\boldsymbol{\sigma}\times\mathbf{r}$ of tensor rank $\lambda=1$:

$$Y=-C_V\int i\boldsymbol{\alpha}+\xi C_V\int\mathbf{r}-\xi C_A\int i\boldsymbol{\sigma}\times\mathbf{r}, \qquad (8)$$

where $\xi=\alpha Z/2R$. ($\alpha=e^2/\hbar c=1/137$; $R=$nuclear radius in units $\hbar=m=c=1$.) The parameter z describes the $\int B_{ij}$ contribution:

$$z=C_A\int B_{ij}. \qquad (9)$$

The coefficient $\lambda_1(Z,W)$ is of order unity and is tabulated in reference 3.

If only the $\int B_{ij}$ matrix element contributes to the β transition ("pure $\int B_{ij}$ transition") the anisotropy factor for a $3^-(\beta)2^+(\gamma)0^+$ β-γ directional correlation becomes

$$A_2(W)=-\frac{2\lambda_1p^2}{7[\lambda_1p^2+(W_0-W)^2]}. \qquad (10)$$

[7] L. C. Biedenharn and M. E. Rose, Revs. Modern Phys. 25, 729 (1953).

[8] M. Ferentz and N. Rosenzweig, Argonne National Laboratory Report No. 5324 (unpublished).

[9] Z. Matumoto, M. Morita, and M. Yamada, Bull. Kobayasi Inst. Phys. Research 5, 210 (1955).

The β-γ anisotropy factor for a $4^-(\beta)2^+(\gamma)0^+$ β-γ-directional correlation involving a unique first-forbidden transition is

$$A_2(W) = +\frac{1}{7}\frac{\lambda_1 p^2}{(W_0-W)^2+\lambda_1 p^2}. \tag{11}$$

Occasionally, β-γ directional correlation studies involve measurements of β γ correlations with an intermediate γ-radiation unobserved. Such a 1–3 directional correlation measurement is designated by $I_0(\beta)I_1\{\gamma_a\}I_1'(\gamma_b)I_2$, where the curly brackets indicate that the γ_a radiation is not observed in the measurement. The directional correlation function of a $\beta \rightarrow \{\gamma_a\} \rightarrow \gamma_b$ cascade is represented by[7]

$$W_{\beta\rightarrow\{\gamma a\}\rightarrow\gamma b}(\theta,W) = 1+\sum_{k=1}^{k_{\max}} A_{2k}{}^{\beta}(W)U_{2k}{}^{\gamma_a}(I_1'I_1)A_{2k}{}^{\gamma_b}P_{2k}(\cos\theta), \tag{12}$$

with

$$\begin{aligned} U_{2k}{}^{\gamma_a}(I_1'I_1) = {} & [(2I_1+1)(2I_1'+1)]^{\frac{1}{2}}(1+\delta_a{}^2)^{-1} \\ & \times\{(-1)^{I_1-I_1'-L_a}W(I_1I_1I_1'I_1';2kL_a) \\ & +(-1)^{I_1-I_1'-L_a'}\delta_a{}^2W(I_1I_1I_1'I_1';2kL_a')\}. \end{aligned} \tag{13}$$

The numbers $W(I_1I_1I_1'I_1';2kL)$ are Racah coefficients. Equation (12) will be important in applying corrections to measured β-γ directional correlations, if competing β-γ cascades are included in the measurements (see Sec. 4).

3. EXPERIMENTAL METHODS

The Sb^{124} was obtained in hydrochloric solution from the Oak Ridge National Laboratory. The sources were prepared by slowly evaporating to dryness a small drop of the solution on a 0.9-mg/cm² Mylar foil. To prevent contamination of the vacuum chamber, the Sb^{124} sources were covered by a thin Zapon film. The thickness of the sources was approximately 0.1 mg/cm². The Mylar foil was glued to a very thin aluminum ring, 5 cm in diameter and 0.2 mm thick. Thus scattering of the β particles near the source was reduced to a minimum.

The vacuum chamber and the detector arrangement used for the Sb^{124} β-γ directional correlation measurements have been described before.[2] The same multichannel coincidence spectrometer electronics was employed as in the previously described β-γ directional correlation studies on K^{42}, Sb^{122}, and Au^{198} (see Fig. 2 of reference 2). The multichannel electronics permitted the simultaneous measurement of β-γ directional correlations between β particles of 3 different energies on one side and two γ rays of different energies on the other side. This method of measurement made it possible to correct the measured β-γ directional correlation data rather accurately for the presence of competing β-γ cascades.

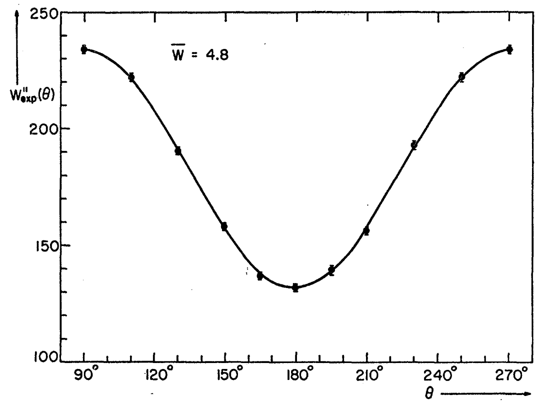

FIG. 2. Integral β-γ directional correlation involving the 2.31-Mev β transition of Sb^{124}. Only β particles of energies larger than 1.59 Mev were accepted in this measurement.

4. MEASUREMENTS AND RESULTS

The angular and energy dependence of the directional correlation between the beta particles of the 2.31-Mev beta group of Sb^{124} and the 0.603-Mev gamma transition leading from the 2^+ excited to the 0^+ ground state in Te^{124} was investigated (Fig. 1).

The unusually large *ft* value of the Sb^{124} β transition under consideration, and the fact that the nonlinear Fermi-Kurie plot is not characteristic of a unique first-forbidden transition, invited the suggestion that the 2.31-Mev β transition might be interpreted as a second-forbidden β transition. On the basis of this consideration a spin of 4^+ was suggested for the Sb^{124} ground state.[10]

In order to investigate the possibility of a second forbidden β transition the *angular* dependence of the β-γ directional correlation was measured. Since the 0.603-Mev γ transition is a pure electric quadrupole, $A_4{}^{\gamma}=F_4(2202)=-1.069$. Thus, an appreciable contribution from a $P_4(\cos\theta)$ term should, in general, be expected if the β transition were second forbidden. The mere presence of a $P_4(\cos\theta)$ term would be a very strong indication of a second-forbidden β transition.

Accepting all β particles with energies greater than 1.59 Mev, the maximum energy of the β_2 group (refer to Fig. 1), the integral β-γ directional correlation was determined as a function of the angle θ between the beta-particle momentum and the gamma momentum vectors. The data were carefully corrected for chance coincidences, background, and the presence of a very small amount of γ-γ coincidences. The average β energy accepted corresponded to $\bar{W}=4.8$. The experimentally determined integral β-γ directional correlation[11] $W_{\exp}''(\theta, \bar{W}=4.8)$ is shown in Fig. 2 and in Fig. 3. No corrections for the finite solid angle subtended by

[10] F. Metzger, Phys. Rev. **90**, 328 (1953).

[11] The double prime indicates directional correlation data which are not normalized to 1 ($\int W''(\theta)d\Omega\neq 4\pi$, i.e., $A_0''\neq 1$), and which are not corrected for finite angular resolution. The prime indicates directional correlation data which are normalized to 1 ($A_0'=1$), but are not corrected for the finite angular resolution of the equipment.

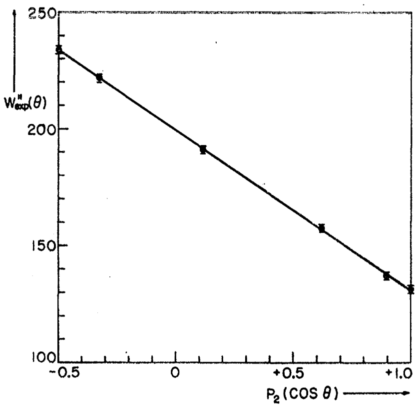

FIG. 3. Integral β-γ directional correlation of the 2.31-Mev β transition of Sb^{124} plotted versus $P_2(\cos\theta)$.

the detectors were applied to these data. The fact that the plot of $W_{\text{exp}}''(\theta, \bar{W}=4.8)$ versus $P_2(\cos\theta)$ results in a straight line is an indication that a $P_4(\cos\theta)$ term, if present, must be very small compared to the $P_2(\cos\theta)$ term.

A least-squares fit of the experimental points of $W_{\text{exp}}''(\theta, W=4.8)$ to a correlation function of the form:

$$W_{\beta\gamma}''(\theta, W=4.8)=A_0''+A_2''(4.8)P_2(\cos\theta)+A_4''(4.8)P_4(\cos\theta), \quad (14)$$

yielded the following values for the normalized $(A_0'=1)$, but uncorrected, anisotropy coefficients $A_i'=A_i''/A_0''$:

$$A_2'(\bar{W}=4.8)=-0.337\pm0.009,$$
$$A_4'(\bar{W}=4.8)=+0.003\pm0.009.$$

Taking into account the corrections for the finite solid angles subtended by the β and the γ detector at the source, one obtains:

$$A_2(\bar{W}=4.8)=-0.390\pm0.011,$$
$$A_4(\bar{W}=4.8)=+0.004\pm0.013.$$

Within experimental error the $P_4(\cos\theta)$ term is zero in the β-γ directional correlation function. The absence of a $P_4(\cos\theta)$ term provides evidence against a second forbidden β-transition and thus against the decay scheme $4^+(\beta_1)2^+(\gamma_1)0^+$. The β transition must be first-forbidden and, as the following directional correlation results show, nonunique. This rules out an assignment of $I=4^-$ to the ground state of Sb^{124}. All experimental evidence is in perfect agreement with a spin assignment of 3^- to the Sb^{124} ground state.

In the following, the β-γ directional correlation data will be analyzed on the assumption that their angular dependence is given by

$$W_{\beta\gamma}(\theta,W)=1+A_2(W)P_2(\cos\theta). \quad (15)$$

Beta-gamma coincidences were measured at 5 different angles: $\theta=90°$, 135°, 180°, 225°, and 270° for a particular β-energy setting of the four β channels. The two γ channels were set to accept the 0.603-Mev (γ_b) and 0.723-Mev (γ_a) photopeak, respectively. If the β channels are set to accept β particles of energies less than the maximum energy of the β_2 transition $(E_{2\,\text{max}}=1.59$ Mev), contributions from the $\beta_2\to\{\gamma_a, 0.723\text{ Mev}\}\to\gamma_b$ triple cascade are also included in the β_1-γ_b coincidence measurements. This $\beta_2\to\{\gamma_a\}\to\gamma_b$ contribution can be accurately calculated, since from the simultaneous β_2-γ_a directional correlation measurements, which give $A^{\gamma_a}A^{\beta_2}(W)$, the $\beta_2\to\{\gamma_a\}\to\gamma_b$ directional correlation can be calculated from Eqs. (5), (12) and (13):

$$W_{\beta_2\to\{\gamma_a\}\to\gamma_b}(\theta,W)=1+A_2^{\beta_2\gamma_a}(W)\times(A_2^{\gamma_b}/A_2^{\gamma_a})U(I,I_1')P_2(\cos\theta).$$

$A_2^{\gamma_a}$, $A_2^{\gamma_b}$, and $U(I,I_1')$ are calculated from the known spin values of the Te^{124} states involved in the transitions $(I_1=2, I_1'=2, I_2=0)$, and from the known multipole character of the γ_a and γ_b transition. γ_a is a mixed $M1+E2$ transition with $\delta_a=(2\|E2\|2)/(2\|M1\|2)=+0.9\pm0.2$.[12,13]

The β-γ coincidence data were first corrected for chance coincidences, including higher order corrections for the fast-slow coincidence arrangement,[14] and for the presence of a small number of γ-γ coincidences. A least-squares fit of the corrected β-γ coincidence data to an expression of the form

$$W_{\beta\gamma}''(\theta)=A_0''+A_2''(W)P_2(\cos\theta),$$

then yielded the values of $A_0''(W)$ and $A_2''(W)$ from which the normalized anisotropy coefficient $A_2'(W)$ was computed (uncorrected for the finite angular resolution). The data taken at $W<W_0(\beta_2)=4.11$ were also corrected for the presence of $\beta_2\to\{\gamma_a\}\to\gamma_b$ coincidences in the manner described above. Corrections for backscattering of the β particles in the plastic

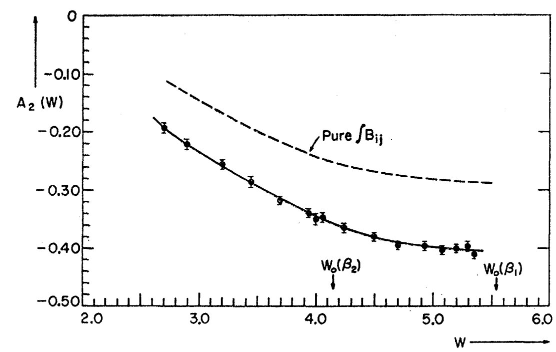

FIG. 4. The anisotropy coefficient $A_2(W)$ of the Sb^{124} β-γ directional correlation measured as a function of the β energy W. The data for $W<W_0(\beta_2)$ are corrected for the presence of the β_2-γ cascade. The dashed curve represents the calculated $A_2(W)$ for a $3^-(\beta)2^+(\gamma)0^+$ cascade involving a "pure $\int B_{ij}$ β transition."

[12] H. Paul, Phys. Rev. 121, 1175 (1961).
[13] T. Lindquist and I. Marklund, Nuclear Phys. 4, 189 (1957).
[14] H. Paul, Nuclear Instr. 9, 131 (1960).

scintillation detector were considered, and found to be small. Finally the geometrical corrections for the finite solid angles of the detectors and for the finite size of the source were applied.

The experimental anisotropy factor $A_2(W)$ for the 2.31-Mev β–0.603-Mev γ cascade of Sb^{124}, measured as a function of the β-energy W, is shown in Fig. 4. The measured β-γ directional correlation agrees very well with recently reported measurements by Fischbeck and Wiedenbeck,[15] and agrees satisfactorily with the results recently reported by Wilkinson *et al.*[16] and by Debrunner *et al.*[17]

The extrapolated value of the anisotropy factor at $W=W_0$, $A_2(W_0)=-0.405\pm0.008$, is remarkably large for a β-γ directional correlation and indicates a sizeable contribution from the tensor-type matrix element $\int B_{ij}$. A unique first-forbidden β transition from a 4^- level of Sb^{124} to a 2^+ state of Te^{124}, however, is excluded in view of the fact that such a transition would result in a positive anisotropy factor $A_2(W_0)=+0.143$ [see Eq. (11)]. Also indicated in Fig. 4 (dotted curve) is the calculated value of $A_2(W)$ for a "pure $\int B_{ij}\,\beta$ transition" in a $3^-(\beta)2^+(\gamma)0^+$ cascade [Eq. (10)]. In Fig. 5 the quantity $A_2(W)(\lambda_2 p^2/W)^{-1}$, which would be independent of β energy if the ξ approximation were valid [cf. Eq. (6)], is plotted. Clearly, the 2.31-Mev β transition displays a strong deviation from the ξ approximation.

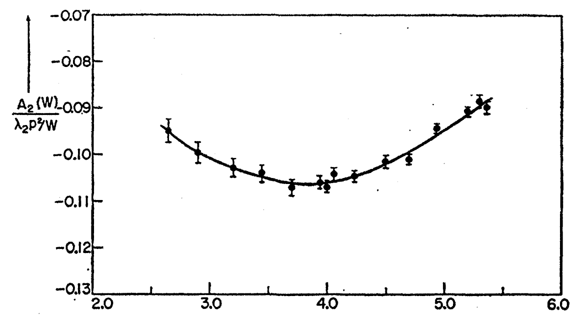

FIG. 5. The experimental quantity $A_2(W)/(\lambda_2 p^2/W)$ versus W. The ξ approximation would predict a constant value for $A_2(W)/(\lambda_2 p^2/W)$.

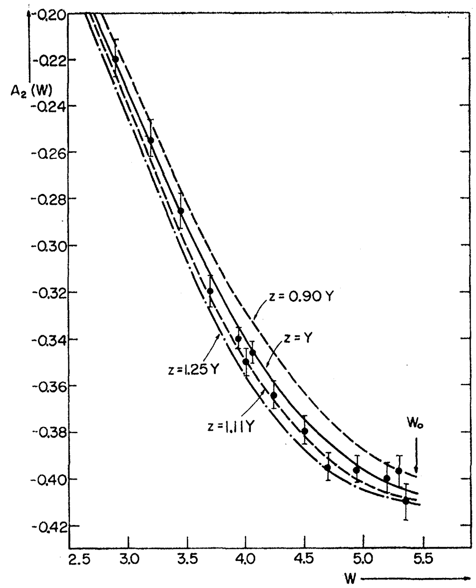

FIG. 6. Comparison of the experimental values of $A_2(W)$ with values computed for different values of the parameter z/Y. The parameter z designates the contribution of $\int B_{ij}$; $z=C_A\int B_{ij}$.

Figure 6 represents an attempt to fit the experimental $A_2(W)$ curve with curves calculated on the basis of the "modified B_{ij}" approximation [Eq. (7)]. A reasonably good fit is obtained with $z=(1.05+0.1)Y$. This value of z/Y also gives a good fit of the spectrum shape factor as measured by Langer and Smith.[5]

The β-γ directional correlation as well as the shape factor data may also be satisfactorily explained by larger values of z/Y, if small contributions of the matrix elements $\int \mathbf{r}$ and $\int i\boldsymbol{\sigma}\times\mathbf{r}$ are accepted. A more rigorous analysis of the data requires the additional information provided by β-γ circular polarization correlation measurements, which are discussed in the following paper.[18] The significant result obtained from the β-γ directional correlation measurements on the $3^-(\beta, 2.31\text{ Mev})\rightarrow 2^+(\gamma, 0.603\text{ Mev})\rightarrow 0^+$ cascade of Sb^{124} is the information that the $\int B_{ij}$ matrix element supplies the major contribution to the 2.31-Mev β transition of Sb^{124}.

It is interesting to note that the same situation prevails in the 1.59-Mev β transition of Sb^{124}, where $z=0.8Y$ or $z=25Y$.[12]

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[15] H. J. Fischbeck and M. L. Wiedenbeck, Bull. Am. Phys. Soc. **6**, 238 (1961).
[16] R. G. Wilkinson, K. S. R. Sastry, and R. F. Petry, Bull. Am. Phys. Soc. **6**, 238 (1961).
[17] P. Debrunner, M. Lambert, A. Poncini, and J. W. Sunier, Helv. Phys. Acta **33**, 985 (1960).
[18] P. Alexander and R. M. Steffen, following paper [Phys. Rev. **124**, 150 (1961).