THE ISOSPIN-FORBIDDEN $\frac{5}{2}^- \to \frac{5}{2}^-$ β-TRANSITION OF ^{65}Ni

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The asymmetry parameter has been obtained from experiments on the $\frac{5^-}{2} \xrightarrow{\beta^-} \frac{5^-}{2} \xrightarrow{\gamma} \frac{3^-}{2}$ circular polarization correlation measurements for the β^- decay of ^{65}Ni. From this, a value for the Fermi nuclear matrix element M_F can be deduced. However, in this case, M_F is dependent on the value of the E2/M1 mixing amplitudes δ for the $\frac{5^-}{2}$ 1116-keV to the $\frac{3^-}{2}$ ground-state γ transition. Our calculation yields a value of $|M_F| = 1.85 \times 10^{-3}$ which is in reasonable agreement with the experimental $|M_F| = 1.6 \times 10^{-3}$ if the E2/M1 mixing amplitude is measured using the technique of angular distribution of γ rays following Coulomb excitation.

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1. *Introduction*

The weighted average value of the asymmetry parameter $\tilde{A} = 0.263 \pm 0.028$ has been obtained from two [1, 2] experiments on the $\frac{5^-}{2} \xrightarrow{\beta^-} \frac{5^-}{2} \xrightarrow{\gamma} \frac{3^-}{2}$ circular polarization correlation measurements for the β^- decay from the ground-state of ^{65}Ni to the $\frac{5^-}{2}$ 1116 keV-state of ^{65}Cu. From this, a value for the Fermi nuclear matrix element M_F can be deduced. However, in this case, M_F is dependent on the value of the E2/M1 mixing amplitude δ for the $\frac{5^-}{2}$ 116-keV to the $\frac{3^-}{2}$ ground-state γ transition.

Two different types of techniques have been used to measure the mixing amplitude δ which have rather different values. The technique using the angular distribution of resonant γ rays [3] yields $\delta = -0.437 \pm 0.015$, resulting in $|M_F| = 0.15 \times 10^{-3}$ whereas the technique using the angular distribution of γ rays following Coulomb excitation [4] gives $\delta = -0.28 \pm 0.05$, yielding $|M_F| = 1.6 \times 10^{-3}$. Obviously, one of the values for δ must be wrong. The aim of this paper is to obtain a theoretical value for M_F in the hope that this might resolve the discrepancy.

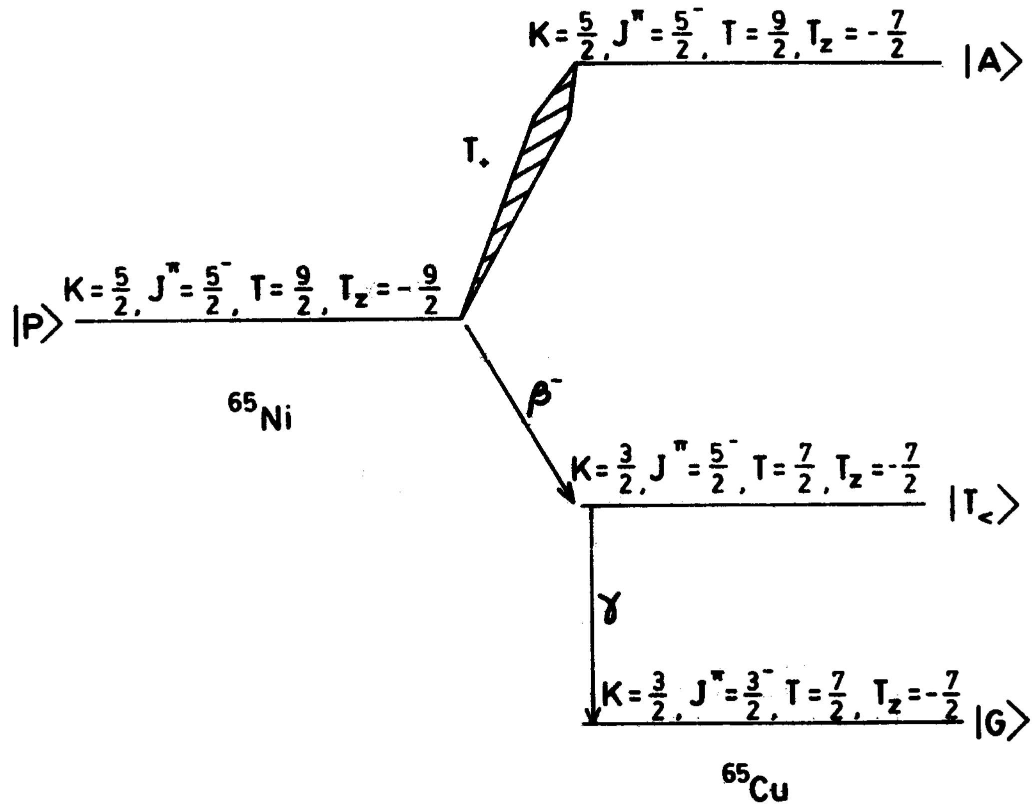

Fig. 1. Partial level diagram for the β^- decay of ^{65}Ni

2. *Calculation and results*

The values M_F for a number of beta-transitions have recently been calculated [5–7] using the Nilsson model [8] with a one-body spheroidal Coulomb potential. As the results show reasonably good agreement between theory and experiment, we shall use the same approach.

We assume that the deformed nucleus ^{65}Ni has the rotational band $K = \frac{5}{2}$ and that the deformed ^{65}Cu has $K = \frac{3}{2}$ as shown in Fig. 1, where $|G\rangle$, $|P\rangle$, $|A\rangle$ and $|T_{<}\rangle$ are the ground state the parent state, the analog state and the anti-analog state respectively. Assuming axially symmetric prolate deformation, the initial state is

$$
\begin{aligned}
|i\rangle &= |J = \tfrac{5}{2}, M, K = \tfrac{5}{2}, T = \tfrac{9}{2}, T_z = -\tfrac{9}{2}\rangle \\
&+\bar{a}_0|J = \tfrac{5}{2}, M, K = \tfrac{3}{2}, T = \tfrac{9}{2}, T_z = -\tfrac{9}{2}\rangle \\
&+\bar{\alpha}_2|J = \tfrac{5}{2}, M, K = \tfrac{5}{2}, T = \tfrac{11}{2}, T_z = -\tfrac{9}{2}\rangle \\
&+ \dots
\end{aligned} \tag{1}
$$

and the final state is

$$
\begin{aligned}
|f\rangle = &|J=\tfrac{5}{2}, M, K=\tfrac{3}{2}, T=\tfrac{7}{2}, T_z=-\tfrac{7}{2}\rangle \\
&+a_1|J=\tfrac{5}{2}, M, K=\tfrac{5}{2}, T=\tfrac{7}{2}, T_z=-\tfrac{7}{2}\rangle \\
&+\alpha_0|J=\tfrac{5}{2}, M, K=\tfrac{3}{2}, T=\tfrac{9}{2}, T_z=-\tfrac{7}{2}\rangle \\
&+\alpha_1 a_1|J=\tfrac{5}{2}, M, K=\tfrac{5}{2}, T=\tfrac{9}{2}, T_z=-\tfrac{7}{2}\rangle \\
&+ \dots
\end{aligned}
\tag{2}
$$

where $\bar{a}_0$ is the admixture amplitude of $K=\frac{3}{2}$ in the initial state and a_1 is that of the $K=\frac{5}{2}$ in the final state.

The relevant isospin impurity amplitudes are given by

$$
\alpha_0 = -\frac{\langle J=\frac{5}{2}, M, K=\frac{3}{2}, T=\frac{7}{2}, T_z=-\frac{7}{2}|V_c|J=\frac{5}{2}, M, K=\frac{3}{2}, T=\frac{9}{2}, T_z=-\frac{7}{2}\rangle}{\Delta E},
$$

$$
\alpha_1 = -\frac{\langle J=\frac{5}{2}, M, K=\frac{5}{2}, T=\frac{7}{2}, T_z=-\frac{7}{2}|V_c|J=\frac{5}{2}, M, K=\frac{5}{2}, T=\frac{9}{2}, T_z=-\frac{7}{2}\rangle}{\Delta E},
\tag{3}
$$

where ΔE is the separation energy and V_c the Coulomb potential.

The Fermi matrix element is

$$
\begin{aligned}
M_F &= \langle f|T_+|i\rangle \\
&= 3(\alpha_0\bar{a}_0+\alpha_1 a_1)
\end{aligned}
\tag{4}
$$

and the Gamow-Teller (GT) matrix element is calculated from the relation

$$
M_{GT}^2 = \frac{1}{2J+1}\sum_{\mu, M_i, M_f} |\langle f|D_{GT}(\mu)|i\rangle|^2. \tag{5}
$$

When the operator $D_{GT}(\mu)$ is transformed into the body-fixed coordinate system, we obtain

$$
\begin{aligned}
M_{GT}^2 = &|\sqrt{\tfrac{2}{7}}\langle \chi_{\frac{3}{2}}\chi^{T=\frac{7}{2}}_{T_z=-\frac{7}{2}}|D'_{GT}(-1)|\chi_{\frac{5}{2}}\chi^{T=\frac{9}{2}}_{T_z=-\frac{9}{2}}\rangle \\
&+\sqrt{\tfrac{9}{35}}\,\bar{a}_0\langle \chi_{\frac{3}{2}}\chi^{T=\frac{7}{2}}_{T_z=-\frac{7}{2}}|D'_{GT}(0)|\chi_{\frac{3}{2}}\chi^{T=\frac{9}{2}}_{T_z=-\frac{9}{2}}\rangle \\
&+\sqrt{\tfrac{5}{7}}\,a_1\langle \chi_{\frac{5}{2}}\chi^{T=\frac{7}{2}}_{T_z=-\frac{7}{2}}|D'_{GT}(0)|\chi_{\frac{3}{2}}\chi^{T=\frac{9}{2}}_{T_z=-\frac{9}{2}}\rangle \\
&+\sqrt{\tfrac{2}{7}}\,\alpha_0\langle \chi_{\frac{5}{2}}\chi^{T=\frac{9}{2}}_{T_z=-\frac{7}{2}}|D'_{GT}(-1)|\chi_{\frac{3}{2}}\chi^{T=\frac{9}{2}}_{T_z=-\frac{9}{2}}\rangle|^2,
\end{aligned}
\tag{6}
$$

where $|\chi_k \chi^T_{T_z}\rangle$ are the intrinsic states, which depend on the deformation parameter β. In this calculation we have used [9] $\beta = 0.2$, and calculation shows that in Eq. (6), the matrix elements of the first and last terms vanish whereas the third term is much larger than the second, which can then be neglected. This results in $M_{GT} = 2.23a_1$ from which the value of a_1 could be calculated if the value of M_{GT} is known.

The experimental value of M_{GT} can be obtained from the following relation:

$$|M_{GT}| = \frac{C_V}{C_A}\sqrt{\frac{2ft\ (\text{superallowed})}{ft\ (\text{decay under study})}}\,\frac{1}{\sqrt{1+y^2}}\,. \tag{7}$$

Owing to the smallness of the experimental value of y, we shall obtain essentially the same value of M_{GT} irrespective of whichever experimental value of y we use.

For the calculation of the isospin impurity as given by Eq. (3), we take V_c to be the one-body spheroidal Coulomb potential given by

$$V_c = \frac{(Z-1)e^2}{R}\left[\tfrac{3}{2}-\tfrac{1}{2}(r/R)^2\right]+a(r/R)^2 Y_{20} \quad \text{fot} \quad r < R,$$

$$V_c = \frac{(Z-1)e^2}{r} + a(R/r)^3 Y_{20} \quad \text{for} \quad r > R, \tag{8}$$

where R is the nuclear radius and a is related to the Bohr deformation parameter β by

$$a = \tfrac{3}{5}\,\beta(Z-1)\,\frac{e^2}{R}\,. \tag{9}$$

Calculation shows that $\alpha_1 \gg \alpha_0$ which can be neglected. Hence, from Eq. (4), the theoretical value of the Fermi nuclear matrix element is given by

$$|M_F|_{\text{theo}} = 1.85\times 10^{-3}.$$

This agrees reasonably well with the experimental $|M_F| = 1.6\times 10^{-3}$ if the E2/M1 mixing amplitude δ is measured using the technique of angular distribution of γ rays following Coulomb excitation [4].

Editorial note. This article was proofread by the editors only, not by the authors.

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