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THE RELATIVELY LARGE FERMI MATRIX ELEMENT OF ISOSPIN-FORBIDDEN $\frac{3}{2}^- \rightarrow \frac{3}{2}^-$ β^+ DECAY OF ^{57}Ni

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Owing to the inhibition due to the ΔK selection rule in β-decay, the calculated value of the Fermi matrix element of the isospin-forbidden β^+ decay of ^{57}Ni is in reasonably good agreement with the experimental value.

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1. Introduction

The Fermi nuclear matrix elements M_F as deduced from β-decay experiments [1] are generally very small for isospin-forbidden Fermi transitions. However, there are three exceptions for which M_F are [2, 3] relatively large: ^{64}Ga → ^{64}Zn; ^{66}Ge → ^{66}Ga and ^{57}Ni → ^{57}Co. The first two are isospin-forbidden $0^+ \rightarrow 0^+\beta^+$ decays while the last one is the only isospin-forbidden $J^\pi \rightarrow J^\pi$ $(J \neq 0)$ β transition with a relatively large M_F. It was found that the experimental value (14.6×10^{-3}) could not be reconciled with the theoretical estimate of $\sim 65 \times 10^{-3}$ using appropriate shell model configurations [4]. Probably, shell--model treatment might not be appropriate as it has been found [5] that, for shell-model calculations on $N = 30$ nuclei with $20 \leqslant Z \leqslant 27$, only ^{57}Co gave poor agreement between theory and experiment, particularly with regard to the $\frac{3}{2}^-$ state at 1.38 MeV which is the parent state of the decay. In this paper we shall use the collective model with Nilsson wave functions, using a small value for the deformation parameter $\beta = -0.1$.

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2. *Calculation and results*

We assume that the deformed nucleus ^{57}Ni has the rotational band $K = \frac{3}{2}$ and that the deformed ^{57}Co has $K = \frac{1}{2}$. (See Fig. 1). The initial and final states with appropriate admixtures by charge-dependent forces and the Coriolis force are:

$$|\mathrm{i}\rangle = |J = \tfrac{3}{2}, M, K = \tfrac{3}{2}, T = \tfrac{1}{2}, T_z = -\tfrac{1}{2}\rangle$$
$$+\bar{\alpha}|J = \tfrac{3}{2}, M, K = \tfrac{3}{2}, T = \tfrac{3}{2}, T_z = -\tfrac{1}{2}\rangle$$
$$+\bar{a}|J = \tfrac{3}{2}, M, K = \tfrac{1}{2}, T = \tfrac{1}{2}, T_z = -\tfrac{1}{2}\rangle$$
$$|\mathrm{f}\rangle = |J = \tfrac{3}{2}, M, K = \tfrac{1}{2}, T = \tfrac{3}{2}, T_z = -\tfrac{3}{2}\rangle$$
$$+a|J = \tfrac{3}{2}, M, K = \tfrac{3}{2}, T = \tfrac{3}{2}, T_z = -\tfrac{3}{2}\rangle,$$

where $\bar{a}$ is the admixture amplitude of $K = \frac{1}{2}$ of the initial state, a the admixture amplitude of $K = \frac{3}{2}$ of the final state and the isospin impurity amplitude $\bar{\alpha}$ is given by

$$\bar{\alpha} = -\frac{\langle J = \frac{3}{2}, M, K = \frac{3}{2}, T = \frac{1}{2}, T_z = -\frac{1}{2}|V_{\mathrm{CD}}|J = \frac{3}{2}, M, K = \frac{3}{2}, T = \frac{3}{2}, T_z = -\frac{1}{2}\rangle}{\Delta E}$$

We shall take V_{CD} to be the one-body spheroidal Coulomb potential [3]. The Fermi matrix element is then given by

$$M_{\mathrm{F}} = \langle \mathrm{f}|T_{-}|\mathrm{i}\rangle = \sqrt{3}\,\bar{\alpha}a.$$

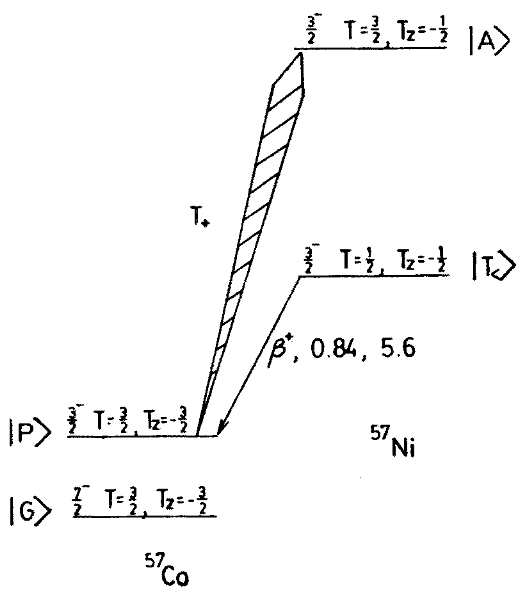

Fig. 1. Partial level diagram for the β^{+}-decay of ^{57}Ni

The $K = \frac{3}{2}$ admixture amplitude $a(= -0.129)$ is determined by calculating the Gamow-Teller matrix element M_{GT} for the transition and requiring it to give the measured ft value ($\log ft = 5.6$) with the aid of the following equation [1]

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

$$= \left(\frac{G_V}{G_A}\right)^2 \frac{2 \times (3088.6 \pm 2.1) \text{ sec}}{ft \text{ (sec)} \times (1+y^2)},$$

where $D_{GT}(\mu)$ is the Gamow-Teller transition operator, G_V and G_A are the weak-interaction vector and axial vector coupling constant respectively and [4] $y = \frac{G_V M_F}{G_A M_{GT}} = -0.118 \pm 0.021$.

After a rather tedious calculation we finally obtained $M_F = -10.5 \times 10^{-3}$ which is in good agreement with the experimental value of $|M_F| = (14.6 \pm 2.9) \times 10^{-3}$.

3. *Conclusions*

Owing to the inhibition due to the ΔK selection rule in β-decay, the calculated value of M_F in the collective model is in reasonably good agreement with the experimental value.

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