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NEW BETA DECAY BRANCHES OBSERVED IN EXOTIC fp-SHELL NUCLIDES

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ℓ-FORBIDDEN GAMOW-TELLER DECAYS AND EXTRA-NUCLEONIC EFFECTS

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1. INTRODUCTION

Extra-nucleonic effects such as Meson Exchange Currents (MEC) and Δ-isobar excitations are expected to play a role in the description of nuclear states at low excitation energies[1], but the influence of these effects is normally masked by more common processes. However, in ℓ-forbidden β transitions ($\Delta\ell$=2) the impulse-approximation matrix elements are small or zero, and the extra-nucleonic effects thus account for most of any observed non-zero decay strength. Studies of such transitions thus offer a promising avenue of exploring the presence of extra-nucleonic degrees of freedom. The $d_{3/2} \rightarrow s_{1/2}$ beta-decay branches of ^{39}Ca and ^{37}K are particularly attractive because of their proximity to a double shell closure, which reduces the uncertainty of shell-model based calculations. We report here measurements of those very weak branches in ^{39}Ca and ^{37}K.

2. EXPERIMENTAL TECHNIQUE

Samples of ^{39}Ca and ^{37}K were produced in ^{39}K(p,n) and ^{40}Ca(p,α) reactions, respectively, at the TASCC facility in Chalk River. Reaction products recoiled out of a stack of 15 thin targets spaced 6 mm apart and were carried by a NaCl aerosol loaded He-jet transport system to a fast tape station in a shielded area. After a sample had been collected for a few half-lives, a tape movement brought it to a counting station equipped with two plastic scintillators and a 68% HPGe detector where β-delayed gamma rays were recorded. The next tape movement brought the sample into a 4π sr gas counter where positrons were multiscaled and the strength of the sample established.

3. RESULTS

The ℓ-forbidden decay branches were observed in the decays of both ^{39}Ca and ^{37}K. In the case of ^{39}Ca it was the only branch observed[2] in addition to the superallowed ground-state branch. Our measurement of the branching ratio agrees with the only previous result[3], but is more precise. The decay of ^{37}K is more complex with 7 beta transitions identified in our experiment, four of them, including the ℓ-forbidden one, previously unknown. The ℓ-forbidden transition from ^{37}K populates the 1410 keV, $1/2^+$ state in ^{37}Ar, but this state is also fed by a 1386 keV gamma transition from a state at an excitation energy of 2796 keV. A portion of our gamma-ray spectrum for ^{37}K is shown in Figure 1, and a partial decay scheme is shown in Figure 2.

Our measured values for the branching ratios of the ℓ-forbidden transitions in ^{39}Ca and ^{37}K are given in Table 1. The size of these transitions can be predicted in calculations that take into account both standard nuclear effects such as core polarization and relativistic corrections as well as extra-nucleonic degrees of freedom. The results of such calculations by Towner[1] are also shown in Table 1.

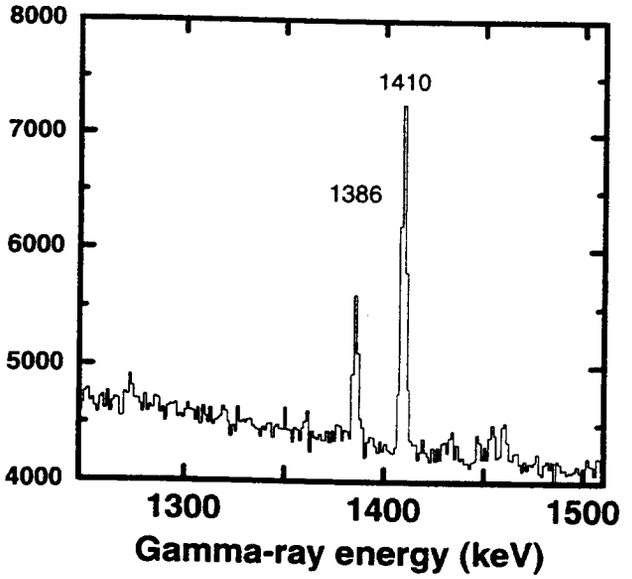

Fig. 1 γ-ray spectrum from ^{37}K

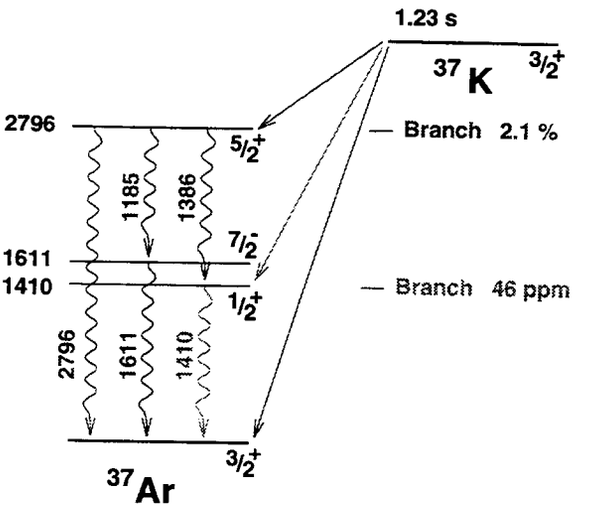

Fig. 2 Partial decay scheme for ^{37}K

Table 1
ℓ-forbidden branch (ppm)

	Experiment	Theory
^{39}Ca	25 (3)	57 (42)
^{37}K	46 (6)	106

The agreement between theory and experiment is fair, but the theoretical uncertainties are very large (that of the ^{37}K case still remains to be estimated). However, a more stringent test is the comparison between the GT matrix elements for these branches with the matrix elements for the analogous isovector M1 γ transitions. Such a comparison results in a large reduction in the theoretical uncertainties because of the similarities of the two operators. In addition, the matrix-element ratio is very insensitive to the particulars of the theoretical model. For the ^{39}Ca case the matrix element ratio $\sqrt{B(M1)/B(GT)}$ is 0.26 from experiment and 1.64 from theory, and reasonable adjustments of the parameters in the theory only alter the ratio by a small amount[2].

4. CONCLUSIONS

We have measured the branching ratios for the weak ℓ-forbidden β-decay branches of ^{39}Ca and ^{37}K and, for the mass 39 case, also compared the transition rate to that of the isovector M1 transition. For the ratio of these quantities there is serious disagreement between experimental results and the microscopic calculations of Towner. The role of extra-nucleonic effect in low energy nuclear states is still not understood.

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