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Properties of low-lying intruder states in ^{34}Al and ^{34}Si populated in the beta-decay of ^{34}Mg

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Abstract.

The results of the IS530 experiment at ISOLDE revealed new information concerning several nuclei close to the $N \approx 20$ ‘Island of Inversion’ - ^{34}Mg , ^{34}Al , ^{34}Si . The half-life of ^{34}Mg was found to be three times larger than the adopted value (63(1) ms instead of 20(10) ms). The beta-gamma spectroscopy of ^{34}Mg performed for the first time in this experiment, led to the first experimental level scheme for ^{34}Al , also showing that the full beta strength goes through the predicted 1^+ isomer in ^{34}Al [1] and/or excited states that deexcite to it. The subsequent beta-decay of the 1^+ isomer in ^{34}Al allowed the observation of new gamma lines in ^{34}Si , (tentatively) associated with low-spin high-energy excited states previously unobserved.

Keywords: HPGe, LaBr₃(Ce) detectors, plastic scintillator, ^{34}Mg , ^{34}Al , ^{34}Si , β^- decay, measured $\gamma\gamma$ coincidences, deduced level scheme.

PACS: 21.10.Tg, 23.20.Lv, 23.40.-s, 27.30.+t,

1. INTRODUCTION

More than three decades after the first clues [2, 3] to the existence of a region of deformation and/or shape coexistence around $N = 20$ - the “Island of Inversion” - there are nuclei in its vicinity for which the experimental information is scarce. Such an example is the heaviest nucleus inside this ‘island’ - ^{34}Mg , whose first beta-gamma spectroscopy was performed in our recent experiment at ISOLDE [4]. The daughter nucleus - ^{34}Al - had no experimental level scheme, though some transitions were assigned to this nucleus [5, 6]. Moreover a low spin beta-isomer of unknown excitation energy was evidenced at GANIL [1], presumably the 1^+ state of $1\hbar\omega$ configuration [4, 7], populating strongly the deformed 0_2^+ isomer in ^{34}Si of intruder origin.

2. EXPERIMENT

The β^- decay spectroscopy of ^{34}Mg was performed at the ISOLDE facility at CERN. The ^{34}Mg isotopes were produced by the CERN Proton Synchrotron Booster (PSB) 1.2-GeV proton-beam which induced spallation in a thick uranium carbide (UCx) target. The reaction products were extracted and ^{34}Mg was selected using the high resolution mass separator (HRS) and resonant laser ionization (RILIS). During the experiment, an yield of ~ 600 ^{34}Mg atoms per proton pulse was obtained, leading to an average of ~ 200 implanted ^{34}Mg per second.

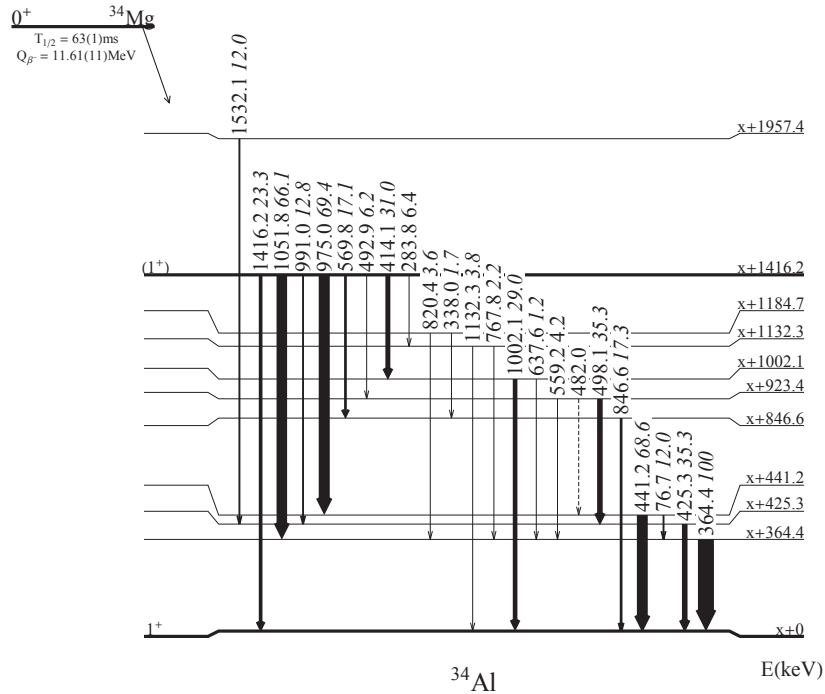


FIGURE 1. Level scheme of ^{34}Al following the β -decay of ^{34}Mg .

The detection system consisted of beta and gamma detectors in order to provide an unique selection of β - γ coincidences and neutron detectors to select β -n and β -2n decay channels. There were three HPGe clover detectors, one HPGe coaxial detector, five LaBr₃:Ce crystals which were used as fast-timing γ detectors and three NE213 liquid scintillators as neutron detectors.

A NE102 plastic scintillator was used as a β trigger of $\sim 90\%$ efficiency. This detector had a complex geometry that was designed to comply with several criteria. First of all, in order to maximize the beta efficiency, the implantation tape (of the fast-tape station) passed through a slit in the middle of the scintillator, a hole through one of the faces allowing the implantation of the beam into the foil. A second constraint was related to the thickness of the plastic that needed to be reduced in order to diminish the effect on the low energy γ efficiency.

3. EXPERIMENTAL RESULTS

The γ spectrum following the β -decay of ^{34}Mg and γ - γ coincidence analysis led to the preliminary ^{34}Al level scheme built on top of the 1^+ isomer, displayed in Fig. 1. None of the 22 gamma transitions from ^{34}Al observed in this experiment are found among the previously reported lines of ^{34}Al (388, 433, 597, 706, 916 and 1206 keV from [5], and 657 keV from [6]). The direct γ transition $1^+ \rightarrow 4^-$ was not observed, most likely as a result of an excitation energy significantly smaller than the 550-keV value predicted by the shell-model calculations in [1], thus leading to a very small γ branch from the 1^+ β -isomeric state. Also, none of the observed transitions could be connected to the 4^- ground state of ^{34}Al , inferring that it is not significantly fed in the β -decay of ^{34}Mg .

The β -decay half-life of ^{34}Mg was determined using the γ -gated β -time with respect to the proton pulse leading to $T_{1/2} = 63(1)$ ms, three times larger than the previously measured value determined from β -n coincidences [8]. This new value is also confirmed by the β time gated using known γ transitions in ^{33}Al (populated in the β -n decay of ^{34}Mg).

The subsequent β -decay of ^{34}Al revealed several new γ transitions in ^{34}Si , γ - γ coincidences leading to the decay scheme depicted in Fig. 2. The newly reported lines are in coincidence with the previously known transitions from the

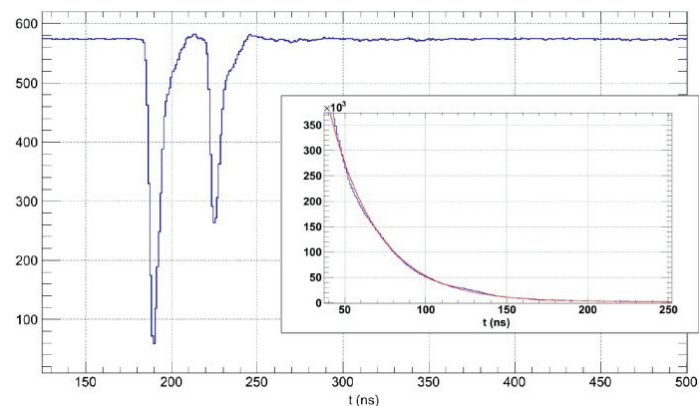


FIGURE 3. Digitized trace from the plastic detector for a 'double hit' type of event. The inset is the time spectrum resulting from the analysis of such traces, leading to a 20(2) ns half-life for the 0_2^+ in ^{34}Si

deexcite to the 1^+ isomer evidenced in [1]. The beta-decay of the 1^+ isomer in ^{34}Al allowed the observation of new gamma lines in ^{34}Si . No β or γ branching was observed to populate the 4^- final state, previously assumed the ground state of ^{34}Al . Therefore, the question remains open, whether the 1^+ or the 4^- is the ground state of ^{34}Al .

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