States in \( N = 79 \) \(^{142}\text{Eu} \) Populated in the Decay of \(^{142}\text{Gd} \)

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The structure of \(^{142}\text{Eu} \) is investigated through the beta decay of \(^{142}\text{Gd} \), whose decay half-life is measured to be \((69.1 \pm 1.0) \) s. A level scheme comprising 42 transitions depopulating 18 excited states is constructed. With the help of the deduced \( f_t \) values and measured internal conversion coefficients, spin-parity assignments are proposed for several states in \(^{142}\text{Eu} \). The level systematics of the doubly odd, \( N = 79 \) isotones are discussed.

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1. Introduction

The transitional characteristics of the neutron deficient nuclides in the \( 50 \leq Z, N \leq 82 \) mass region have continued to attract a considerable interest \([1]\). The nuclei with \( 76 \leq N \leq 82 \) and \( Z \leq 63 \) have been the subject of a number of our earlier studies \([2-13]\). The present work therefore represents an extension to the \( Z = 64 \) isotopes.

The nuclide \(^{142}\text{Gd} \) was first identified by the Karlsruhe group in 1973 \([14]\). They reported a \( \gamma \)-ray of 179 keV from its decay with an approximate half-life of 1.5 m. From the work of Kennedy et al. \([3]\), the daughter nucleus \(^{142}\text{Eu} \) is known to have a \(^1\text{g}\) ground-state \( (T_{1/2} = 2.4 \pm 0.2 \) s) and a \(^7\text{g}\) isomeric state \( (T_{1/2} = 1.22 \pm 0.02 \) m). The nuclide \(^{142}\text{Gd} \) has also been studied by in-beam spectroscopy experiments. Following the bombardment of \(^{144}\text{Sm} \) with 105 MeV alpha particles, Mariscotti et al. \([15]\) observed an yrast cascade which they assigned to \(^{142}\text{Gd} \) on the basis of excitation function systematics in this region. More recently, Lunardy et al. \([16]\) performed careful excitation function measurements for the \(^{144}\text{Sm} \) \((\alpha, \alpha n y p)\) reactions and demonstrated that the \((\alpha, 6n)\) channel, leading to \(^{142}\text{Gd} \), should peak at 95 MeV and not at 105 MeV. Earlier measurements performed by us \([17]\) are in agreement with their conclusions.

Very little else was thus known about the structure of the doubly odd \(^{142}\text{Eu} \) nuclide and about the decay properties of its parent \(^{142}\text{Gd} \). Our study was undertaken \([18]\) as an effort to study the structure of the odd-odd nuclides of this transitional region for which there is a lack of systematic information.

2. Experimental Techniques

The nuclide \(^{142}\text{Gd} \) was produced in the McGill synchrocyclotron through the \((^3\text{He}, 5n)\) reaction on \(^{144}\text{Sm} \) targets isotopically enriched to 91%. The sources produced in this reaction were transported to a low background counting area by means of a gas-jet recoil-transport (GJRT) system. This system, which is using a mixture of 5% ethylene \((C_2H_4)\) and 95% helium by volume, is capable of extracting reaction products from internal cyclotron bombardments with an overall efficiency of 70% and with a transit time of 600 ms. The radioactive samples were deposited on the surface of a programmable tape transport system so that sources could be collected, allowed to cool, and automatically moved in front of the detectors in a repeating cycle in order to maximize counting efficiency. The targets were prepared by pressing \(^{144}\text{Sm}_2\text{O}_3\) powder on thin aluminum backing \((6.75 \text{ mg/cm}^2)\) following a method already described by Kosanke et al. \([19]\).

Gamma-rays were measured with two 25% efficiency \(n\)-type Ge(Hp) detectors of energy resolution 2.0 and 2.1 keV, respectively, for a 1.3 MeV \( \gamma \)-ray. Low energy \( \gamma \)-rays and X-rays were measured with a hyperpure Ge X-ray spectrometer of energy resol-
Fig. 1. Top sectional view of the mini-orange spectrometer used in the present work. The geometry used for $\gamma-\gamma$ coincidence measurements is also shown.

450 eV for the 122 keV transition in $^{57}$Co. Gamma-ray singles spectra were calibrated for energy and intensity using $^{133}$Ba, $^{152}$Eu and $^{207}$Bi sources counted in the same geometry as the unknown samples. X-$\gamma$ and $\gamma-\gamma$ ray coincidence measurements were performed using any combination of two of the above detectors together with standard fast-slow coincidence electronics and X-$\gamma-t$ or $\gamma-\gamma-t$ triplets were stored sequentially on magnetic tape.

Conversion electron spectra were measured using a “mini-orange” spectrometer coupled to the GJRT system. It consists of a 300 mm $^2$ x 4 mm Si(Li) detector assembly and a set of mini-orange magnetic filters similar in design to those reported by Ishii [20]. The detector itself, together with the preamplifier input FET, is enclosed in a stainless steel cylinder and is coupled to a cold finger. The front face of this cylinder is sealed with a 2.5 $\mu$m thick (345 $\mu$g/cm$^2$) Mylar window in order to isolate the detector assembly from the gas-jet environment. Good vacuum ($\approx 10^{-6}$ torr) is maintained inside the assembly using zeolite packed around the base of the cold finger which is dipped into liquid nitrogen. This arrangement provides a detection system capable of good energy resolution (typically 2.5, 1.8 and 2.2 keV for electrons with 100, 200 and 1000 keV energy, respectively). The filter used in the present work is made of three strong permanent magnets mounted around a central lead absorber. The latter is 3.7 cm long and practically eliminates the direct solid angle for the detection of photons. The SmCo$_5$ magnets have a flat trapezoidal shape (length: 31.5 mm; top: 25.5 mm; bottom: 16 mm; thickness: 3 mm); they are magnetized along their shortest axis and the magnetic field intensity at their surface varies between 1.2 and 1.9 kG. This filter is placed between the source and the detector. The distances between the source, the filter and the detector were chosen to give a broad transmission covering an energy range from 50 keV to 1 MeV. The approximate toroidal field is used to separate positrons and electrons; as a result, high quality electron spectra can be obtained with little interference from the high flux of positrons, X-rays and $\gamma$-rays emitted from the source. The spectrometer has been calibrated using $^{152}$Eu and $^{207}$Bi conversion electron sources. A top sectional view of the complete spectrometer is shown in Fig. 1. Also illustrated are two Ge(Hp) $\gamma$-ray detectors. One of them (facing the Si(Li) detector) is used to count $\gamma$-rays concurrently with the counting of electrons while the other one can be used to perform $\gamma-\gamma$ coincidence measurements.

In order to measure the half-life of the decaying nuclide, the $\gamma$-ray intensity was monitored as a function of time using a ramp generator (BNC model LG-1) somewhat modified for this particular application. Upon receiving an external trigger signal, this unit provides an output pulse whose height is proportional to the time elapsed since the ramp was started. The ramp can be started and reset by an external clock and has a variable time constant that can be optimized for a particular measurement. In the present work, this unit was triggered by the signals originat-