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Nuclear Physics A 747 (2005) 131–151

NUCLEAR PHYSICS A

Single-proton-transfer studies of ^{153}Eu levels

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Received 30 August 2004; accepted 1 October 2004

Available online 18 October 2004

Abstract

Levels in ^{153}Eu have been studied with the (t, α) reaction at 15 MeV. Earlier (^{3}He, d) and (α, t) results have also been supplemented by new measurements with improved resolution at selected angles. Spectroscopic strengths were extracted, using distorted wave Born analysis methodology, and interpreted in terms of the Nilsson model with Coriolis mixing. Several new level and band assignments are proposed. For the $5/2^+$ levels at 694 and 706 keV an interpretation consistent with all experimental data requires admixtures of the $1/2^+[420]$ and $5/2^+[402]$ orbitals, as well as other types of components. Specifically, in addition to the $5/2^-[532] + Q_{30}$ components previously proposed to explain gamma-decay modes of these levels, (t, p) results indicate that complex configurations involving pairing excitations are important for the 706 keV and other $5/2^+$ levels. The $5/2^+[402]$ strength is fragmented over several levels.

A successful description of these complex structures will require consideration of several effects, including quasiparticle–phonon interactions, Coriolis mixing, and a detailed treatment of pairing correlations.

PACS: 25.55.Hp; 27.70.+q; 21.10.Pc; 21.10.Re

Keywords: NUCLEAR REACTIONS ^{154}Gd(t, α), $E = 15$ MeV; Measured $\sigma(E_\alpha)$, ^{152}Sm(^{3}He, d), $E = 24$ MeV; Measured $\sigma(E_d)$, ^{152}Sm(α, t), $E = 25$ MeV; Measured $\sigma(E_t)$; Deduced ^{153}Eu levels, ℓ-values, spectroscopic strengths; Enriched targets, magnetic spectrographs; Energy resolutions 10–13 keV (FWHM); Comparison with strength predictions for Nilsson model with Coriolis mixing

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0375-9474/$ – see front matter
doi:10.1016/j.nuclphysa.2004.10.001

1. Introduction

The nuclear levels of ^{153}Eu have been studied by many different experimental techniques [1], but no single-proton-pickup results have thus far been reported. This work presents data from the ^{154}Gd(t, α) reaction, and thus provides new information on proton hole states in ^{153}Eu. Although angular distributions for the ^{152}Sm(^{3}He, d) reaction [2] and some ^{152}Sm(α, t) results [3] have been published previously, new results with improved resolution measured at selected angles for these reactions are reported here to assist in clarifying finer details of the spectra.

Special consideration has been focussed on a series of positive parity levels above an excitation energy of ~ 600 keV. The structures of these levels pose an interesting challenge, and predictions of several theoretical studies [4–6] can be compared with the present single-proton-transfer data. The experimental procedures and results are presented in Section 2, and discussion of the nuclear structure is found in Section 3.

2. Experimental details and results

The (t, α) measurements were performed with beams of 15 MeV tritons from the FN tandem Van de Graaff accelerator at the Los Alamos Scientific Laboratory. Reaction products were analysed with the Q3D magnetic spectrometer and detected with a helical-cathode delay-line detector [7]. The target was prepared from a sample of Gd_2O_3, isotopically enriched to 99.35% ^{154}Gd, purchased from the Isotope Sales Division of the Oak Ridge National Laboratory. The Gd_2O_3 was reduced with thorium metal by heating in vacuum and the gadolinium metal was simultaneously vacuum-evaporated onto a carbon foil. The target thickness, determined from intensities of elastically scattered beam particles, was ~ 38 μg/cm^2. Spectra were obtained at reaction angles of $\theta = 15°$, 20°, 30°, and 45°, each with an energy resolution of ~ 13 keV full-width at half maximum (FWHM). Fig. 1 shows the spectrum at $\theta = 45°$.

For the (^{3}He, d) and (α, t) measurements, beams of 24 MeV ^{3}He and 25 MeV α particles from the McMaster tandem Van de Graaff accelerator were used with targets of ^{152}Sm prepared in a manner similar to that described above. The targets used had thicknesses ranging from 20 to 30 μg/cm^2, and an isotopic enrichment of 98.29%. Reaction products were analysed with an Enge split-pole magnetic spectrograph and detected with photographic plates. (^{3}He, d) measurements were made at five angles between $\theta = 10°$ and $\theta = 45°$. The spectrum with the best resolution, of ~ 12 keV FWHM, was at $\theta = 30°$ and is shown in Fig. 2. (α, t) measurements were made at angles of 6°, 15°, 40°, 60°, and 90°. The spectrum shown in Fig. 3 was from a long exposure using a thin target and had the best resolution achieved, ~ 10 keV FWHM. Although the intensities are small for weaker peaks in this spectrum, the data are corroborated and supplemented by results from another spectrum at the same angle with much better statistics due to a thicker target, but with slightly poorer resolution.

For all measurements, normalization factors to convert intensities of peaks in the spectra to absolute cross sections were obtained with cooled silicon surface-barrier monitor counters in the target chambers, which recorded elastically scattered beam particles (at $\theta = 45°$