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ISOMERIC RATIOS FOR NUCLEI WITH Z =62–67 AND A =142–152 PRODUCED IN THE RELATIVISTIC FRAGMENTATION OF ^{208}Pb* **

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Isomeric states in nuclei with $Z = 62$–67 and $A = 142$–152 produced in the fragmentation of the relativistic (1 GeV/nucleon) ^{208}Pb beam were investigated. Isomeric ratios were determined for 10 isomeric states. Significant differences between theoretical and experimental values were observed.

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1. Introduction

We have investigated isomeric states in a number of nuclei with $Z = 62$–67 and $A = 142$–152. They were produced in the fragmentation of the relativistic (1 GeV/nucleon) ^{208}Pb beam from the SIS-18 synchrotron of the GSI facility on a ^{9}Be target, and selected by the FRagment Separator (FRS). The selected nuclei of interest were implanted into a 7 mm thick plastic stopper. The gamma-rays from the decay of isomeric states in the implanted nuclei were measured using the high purity germanium array, RISING [1]. Details of the experiment are described in Ref. [2, 3].

2. Data analysis

In total 22 nuclides were detected, isomeric states were observed in 9 of them (see Table I and Fig. 1). Of special interest is the $I^{\pi} = 27^{+}$ state in ^{148}Tb, as this is the highest spin that has been populated via the fragmentation reaction until now. The aim of this work was the extraction of experimental isomeric ratios (R) for these isomeric states. The ratio R is the number of ions populated in a given isomeric state compared to the total number of ions populated for the selected nuclide. The value of R

TABLE I

Theoretical and experimental isomeric ratios obtained in this work. Half-lifes taken from given references.

Nucleus	Spin	$T_{1/2}$ [μs]	R_{th} [%]	R_{exp} [%]
^{152}Ho	19^{-}	8.4(3) [7]	15.7	6.4(18)
^{153}Ho	$31/2^{+}$	0.25(2) [8]	24.5	16.9(42)
^{148}Tb	27^{+}	1.31(1) [9]	2.1	1.9(3)
^{144}Gd	10^{+}	0.15(3) [10]	59.0	10.3(46)
^{147}Gd	$49/2^{+}$	0.76(4) [11]	4.4	1.1(3)
^{143}Eu	$11/2^{-}$	50.(1) [12]	88.9	12.8(17)
^{144}Eu	8^{-}	1.0(1) [13]	76.4	17.1(20)
^{145}Eu	$11/2^{-}$	0.49(3) [14]	88.7	21.7(28)
^{142}Sm	10^{+}	0.48(6) [15]	59.8	2.0(7)
^{142}Sm	7^{-}	0.17(2) [16]	88.2	21.5(46)

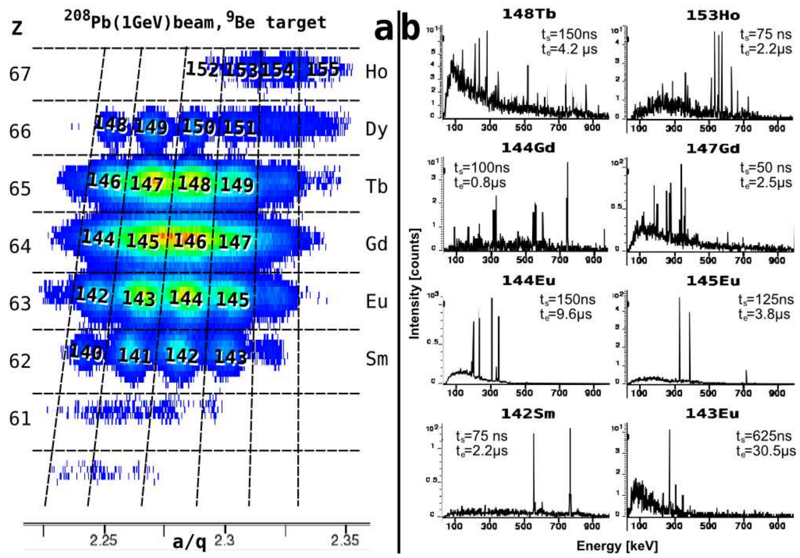

Fig. 1. Panel (a): An identification plot for the nuclei studied. Panel (b): Gamma spectra for selected nuclei measured within the indicated time intervals (t_s, t_e) after implantation in the stopper.

can provide information about the production reaction and nuclear structure. It was evaluated based on time-of-flight, half-life, in-flight losses and by considering the finite measurement time (see Refs. [5, 6] for details).

3. Theoretical predictions

Theoretical isomeric ratios, $R_{\rm th}$, were determined for a series of nuclei, using a formula based on the abrasion–ablation model [4] to predict the energies and spins of nuclei populated in fragmentation reactions. In the sharp cutoff approximation all nuclei of spin higher than that selected decay to that level. Therefore the isomeric ratio of the selected isomer is the integral of the spin distribution (P_I) for spins higher than that of the isomer (I_m):

$$R_{\rm th} = \int\limits_{I_m}^{\infty} P_I dI = \exp\left[-\frac{I_m(I_m+1)}{2\sigma_f^2}\right], \tag{1}$$

$$\sigma_f^2 = 0.16 A_p^{2/3} \frac{(A_p - A_f)(\overline{\nu} A_p + A_f)}{(\overline{\nu}+1)^2 (A_p - 1)}, \qquad \overline{\nu} \approx \frac{N_n}{N_s} \approx \frac{E_n^*}{E_s}, \tag{2}$$

where $\overline{\nu}$ is the ratio of energy transferred during the abrasion of one nucleon (E_n^*) and the energy needed to evaporate one nucleon (E_s).

4. Results and conclusions

The experimental results obtained were compared to theoretical predictions [4] (see Fig. 2a and Sec. 2). Significant differences between experiment and theoretical predictions were observed, just as in Refs. [17,18]. In general, there is relatively good agreement with the analytical formula for high spins (above the spin cut-off parameter σ_f). However, for lower spins (below σ_f) there is no agreement at all. Very analogous behaviour has been observed in similar measurements on nuclei in the $A \approx 85$ mass region [19] (see Fig. 2b).

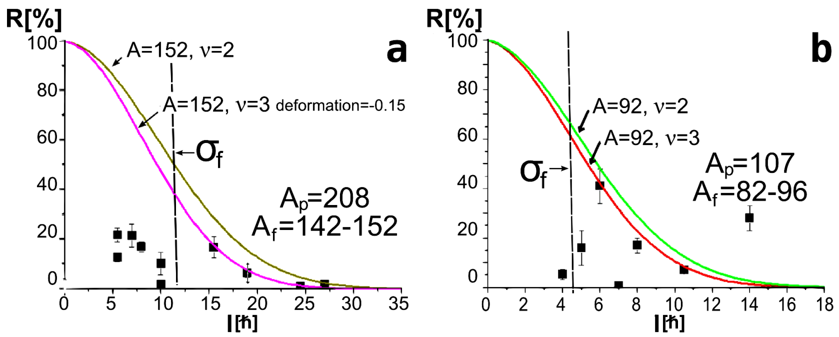

Fig. 2. Comparison between theoretical predictions and experimental results for the present data (panel (a)) and nuclei in $A \approx 85$ mass region [6,19] (panel (b)).

This puzzle will be further investigated, both experimentally and theoretically. There are numerous effects which can contribute to such behaviour. Among them are transitions which bypass the isomeric state or spin loss due to particle evaporation during de-excitation. One can also speculate that in the case of several nucleons removed from the projectile, the reaction mechanism may be more complicated than a simple pure fragmentation process [20,21].

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