THE ROTATIONAL BAND ON THE 9^- ISOMER IN ^{180}Ta * **

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In-beam Coulomb excitation of the $K^\pi = 9^-$ isomer in ^{180}Ta was studied with ^{32}S and ^{58}Ni beams. Excited levels in ^{180}Ta were identified by comparison of results with a natural (0.01%) and an enriched (5.6%) target. The rotational band built on the 9^- isomer could be followed up to the 16^- level and the cascade-to-crossover branching ratios are consistent with a spin-independent value for $(g_K\text{-}g_R)/Q_0$.

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1. Introduction

Although the extremely rare nucleus ${}^{180}_{73}Ta_{107}$ has been the object of intensive investigations over the past decade ([1] and references therein) the mechanism of its formation and of its survival in the stellar medium remains an open question [2]. From the details of the complex level scheme of this odd-odd nucleus, surviving in nature in an excited-state isomer ($K^{\pi} = 9^{-}$, $E_x = 75.3$ keV, $T_{1/2} > 1.2 \times 10^{15}$ y), one may hope to learn how it was formed and how it managed to survive in the excited state. The direct transition from the 9^{-} isomer to the ground state ($K^{\pi} = 1^{+}$, $T_{1/2} = 8.15$ h) is highly K forbidden, but if the nucleus is exposed to an intense photon bath under stellar burning conditions it may be transferred to the ground state via an intermediate state whose detailed properties are yet unknown [3]. The investigations presented here do not aim at detecting this intermediate state but they determine the parameters of the rotational band built on the isomer which can serve as benchmarks for realistic nuclear-structure calculations of this exotic odd-odd nucleus [4].

2. Experimental procedure

About 0.4 mg of Ta_2O_5 powder, enriched to 5.6% in ^{180}Ta, was used to produce a 700 μg/cm^2 thick target by evaporation from a 2.5 mm inside-diameter Re tube onto a 36 μg/cm^2 carbon backing [5]. A target from non-enriched Ta_2O_5 powder was produced in the same way.

The experiments with 125 MeV ^{32}S projectiles, carried out at the tandem-accelerator laboratory in Munich, used an array of 24 1 cm x 1 cm PIN diodes to detect backscattered projectiles, in coincidence with 5 BGO-suppressed gamma spectrometers [6]. For the 225 MeV ^{58}Ni bombardments with the NORDBALL gamma detector at the Niels Bohr Institute in Denmark, a particle-detector array was developed accommodating up to 110 0.5 cm x 0.5 cm PIN diodes inside a 10 cm diameter target chamber [7, 8]. Coincidences were recorded between 55 PIN diodes and NORDBALL's Compton-suppressed Ge counters. The high efficiency of this arrangement provided sufficient statistics to evaluate backscattered projectile-gamma-gamma triple coincidences.

3. Results

A p-γ-γ triple coincidence spectrum shows lines ascribed to the band built on the 9^{-} isomeric state. The transition energies and gamma-ray branching ratios are given in Table I. Bombarding energies chosen to lie well below the Coulomb barrier ensure that the observed lines do not originate from reactions other than pure Coulomb excitation. The lines ascribed to

TABLE I

Spin and parity I^π, excitation energy E^*, transition energy ΔE, moment-of-inertia J_o, branching ratio λ and rotational-parameter combination $(g_K - g_R)/Q_0$ for the 9^- rotational band.

I^π [$\hbar$]	E^* [keV]	ΔI^π [$\hbar$]	ΔE [keV]	J_o [$\hbar^2$/MeV]	λ	$\left\lvert\frac{(g_K-g_R)}{Q_0}\right\rvert$ [b^{-1}]
9^-	75.30(14)	-	-	-	-	-
10^-	278.4(2)	$10^- \to 9^-$ -	203.1(1) -	49.24(2) -	-	-
11^-	503.7(2)	$11^- \to 10^-$ $11^- \to 9^-$	225.3(1) 428.4(2)	48.82(2) 49.02(2)	0.221(10)	0.0491(13)
12^-	751.1(4)	$12^- \to 11^-$ $12^- \to 10^-$	247.4(6) 472.7(6)	48.5(1) 48.66(6)	0.49(11)	0.0485(64)
13^-	1019.6(3)	$13^- \to 12^-$ $13^- \to 11^-$	268.5(3) 515.9(3)	48.42(5) 48.46(3)	0.85(12)	0.0462(34)
14^-	1308.9(3)	$14^- \to 13^-$ $14^- \to 12^-$	289.2(3) 558.0(4)	48.41(5) 48.39(3)	1.02(34)	0.051(10)
15^-	1618.2(4)	$15^- \to 14^-$ $15^- \to 13^-$	309.1(5) 598.7(4)	48.53(8) 48.44(3)	0.92(46)	0.063(17)
16^-	1945.9(6)	$16^- \to 15^-$ $16^- \to 14^-$	327.4(9) 637.1(7)	48.9(2) 48.66(5)	1.4(9)	0.056(20)

^{180}Ta were not seen when using the natural Ta target. For the transitions below the 14^- level our data agree with the properties found in the decay of a 45 μs 15^- isomer at 1.451 MeV populated in compound-nuclear reactions [9, 10]. In the axially symmetric rotational model the cascade-to-crossover branching ratio is given [11] by the combination $(g_K\text{-}g_R)/Q_0$ of the intrinsic parameters g_K (gyromagnetic ratio of the two odd particles), g_R (gyromagnetic ratio of the rotating core), and Q_0, the intrinsic quadrupole moment. Our results show that within experimental errors a single value of

$(g_K\text{-}g_R)/Q_0$ accounts for all six measured branching ratios indicating not a strong mixing with the many other low-lying bands which result from coupling of the odd proton to the neutron [12]. A final analysis will have to include an evaluation of the Coulomb-excitation process with the aim of obtaining absolute B(M1) and B(E2) values.

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