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Population of yrast states in ^{191}Os using deep-inelastic reactions

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Abstract

Several nuclei in the $A \sim 190$ region have been studied following deep-inelastic reactions using a 460 MeV ^{82}Se projectile impinging upon a thick ^{192}Os target. The GASP array (at the Legnaro National Laboratory in Italy) was used to measure the resulting γ-decays. The previously reported near-yrast structure of ^{191}Os is extended to a $t_{\frac{1}{2}} = 61$ ns isomer, at an energy of 2640 keV. Branching ratios for $\Delta I = 1$ and $\Delta I = 2$ transitions in the $K^\pi = \frac{11}{2}^+$ band have been measured, giving $|(g_K - g_R)/Q_0| = 0.022(3)$ and 0.024(7) for transitions from the $\frac{17}{2}^+$ and $\left(\frac{19}{2}^+\right)$ states respectively. These are consistent with the theoretical calculation for the proposed $\nu 11/2^+[615]$ configuration of the band. Nilsson plus BCS calculations reveal that the isomer is likely to have a $\{\nu 11/2^+[615] \otimes \pi 11/2^-[505] \otimes \pi 9/2^-[514]\}$ configuration with $J^\pi = K^\pi = \frac{31}{2}^+$. This yields an implied reduced hindrance of $f_\nu = 1.9$, in accordance with empirical systematics of K isomers in the $A \sim 180$–190 region.

1. Introduction

The $A \sim 190$ region reveals many facets of nuclear structure including K-isomerism [1], γ-softness [2] and oblate–prolate shape transition [3]. However the spectroscopy of neutron-rich nuclei in this mass region at high spins is somewhat sparse. Using a variety of reaction techniques, such as projectile fragmentation [4] or deep-inelastic multi-nucleon transfer reactions [3], combined with powerful detector arrays, it is now possible to access nuclei in this region. Here we report new results for ^{191}Os.

2. Experimental details and analysis

A broad swathe of nuclei in the $A \sim 190$ region was populated using a deep-inelastic reaction between a ^{82}Se projectile incident upon an isotopically enriched (97.8%), ^{192}Os (50 mg cm^{-2}) target backed with 0.2 mm of ^{181}Ta. The subsequent γ-decays were detected using the GASP array [5], in configuration I, at the Laboratori Nazionali di Legnaro, Italy. The array consists of 40 high purity Compton suppressed germanium detectors combining to a 3% absolute photo-peak efficiency at 1332 keV, and an 80 element BGO ball acting as a multiplicity filter. Triggering events of multiplicity 3 Ge + 2 BGO and 2 Ge + 2 BGO detectors were recorded to magnetic tape for approximately 3 days of beam time each.

The experiment has yielded an abundance of new spectroscopic information in both the projectile-like [6, 7] and target-like [7, 8] species. Due to the lack of particle identification, coincidences in unknown binary partner nuclei and a large number of γ-rays with comparable energies in the populated regions, it can be very difficult to obtain precise spectroscopic information in a given nucleus. It is necessary to have a knowledge of low lying near-yrast transitions in the nucleus which can be used as gates in γ-ray coincidence techniques to determine weaker transitions between higher-spin states. Low-spin yrast transitions from Garrett *et al* [9] were used for this purpose in the case of ^{191}Os. The previously reported level structure has been extended from $\left(\frac{19}{2}^{+}\right)$ to $\left(\frac{31}{2}^{+}\right)$ in the current work.

The most intense transitions for ^{191}Os are shown in the spectrum of figure 1(a), corresponding to the proposed level scheme in figure 1(b). The 61 ns isomer identified by Valiente-Dobón *et al* [10] has been populated in this experiment. The energy of the isomer is determined to be 2640 keV, de-excited by a 453 keV γ-ray to the $\left(\frac{27}{2}^{+}\right)$ state of the yrast $\nu 11/2^{+}[615]$ band. Transitions above and below the isomer were studied using a variety of time-restricted, asymmetric γ–γ–γ and γ–γ–time cubes. This helped to clarify the structure depopulating the isomer, and has enabled the identification of candidates for yrast transitions with higher spin. Gating conditions placed upon these cubes have revealed γ-rays above the isomer, the most intense of which have energies of 254, 335, 496 and 603 keV. Each of these transitions is individually coincident with delayed transitions in ^{191}Os (a sum spectrum is shown in figure 1(a)). However, the weak intensities of these transitions have made it difficult to establish their sequence, and the level scheme above the isomer does not figure explicitly in this report.

Tentative spin assignments have been made based upon the continuation of the strongly coupled rotational $\frac{11}{2}^{+}$ band. DCO and angular distribution analysis could not determine unambiguously the multipolarities of any of the transitions. The 330 and 219 keV transitions are marked as tentative due to their weak intensities.

3. Discussion

Despite the low intensities of the intraband M1 transitions, $\Delta I = 1$ and $\Delta I = 2$ transition branching ratios were measured using γ-ray coincidences above and below the states to

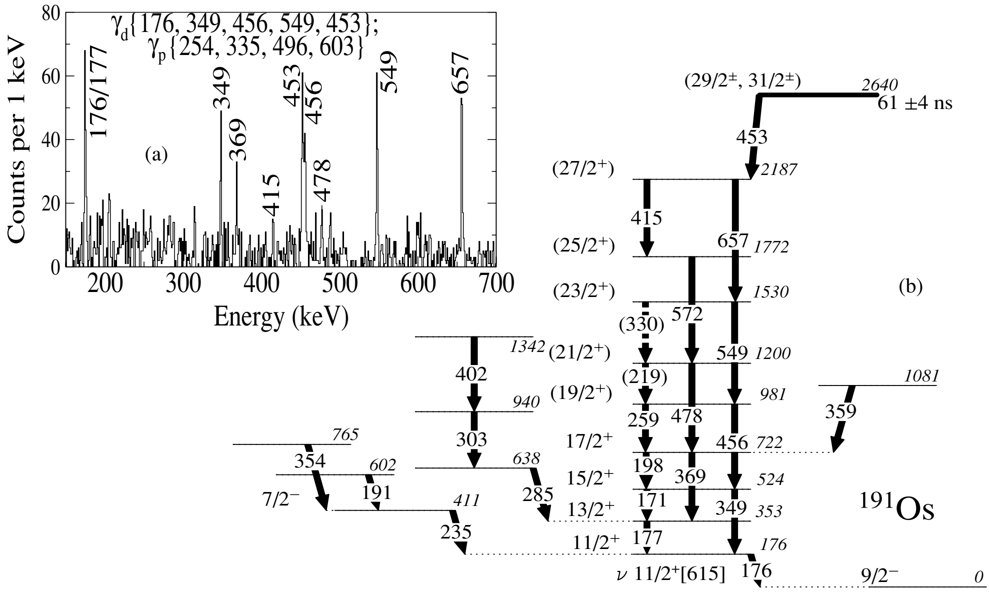

Figure 1. (a) Gamma-ray spectrum highlighting the transitions in ^{191}Os. The spectrum was created using an asymmetric cube demanding that two 'delayed' γ's arrive within 35 ns of each other and between 15 and 100 ns after a 'prompt' γ-ray. The energies of the 'prompt', γ_p, and 'delayed', γ_d, transitions summed to project the second 'delayed' coincidence are listed in brackets. (b) Level scheme for ^{191}Os showing transitions below the 61 ns isomer, as deduced in the current work.

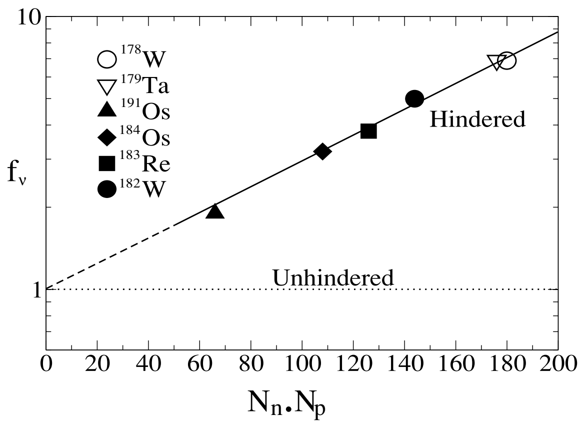

Figure 2. Truncated systematics showing the reduced hindrance f_ν, of E2 isomeric transitions, in different nuclei from the $A \sim 180$–190 region, as a function of the product of valence neutrons N_n, and protons N_p, adapted from Walker *et al* [14, 15]. Filled symbols refer to $\Delta K = 10$ transitions, and open symbols have $\Delta K = 6$.

be measured. Using standard procedures, following for example [12], experimental values are $|(g_K - g_R)/Q_0| = 0.022(3)$ and 0.024(7) from the $\frac{17}{2}^+$ and $\left(\frac{19}{2}^+\right)$ states, respectively. Theoretical estimates for $|(g_K - g_R)/Q_0|$ were calculated using $Kg_K = \Sigma_i(g_\Lambda \Lambda + g_\Sigma \Sigma)$, with a quenching factor of 0.6 for the intrinsic g-factors, $g_R = 0.35$ and $Q_0 = 4.7$ eb, taken as a mean of values for ^{190}Os and ^{192}Os [13]. Calculations for the yrast $\nu 11/2^+[615]$ configuration yield a value of $|(g_K - g_R)/Q_0| = 0.019$, which is in good agreement with the experimental values.

New spin and energy information enables us to make comparisons with the Nilsson plus BCS models [11] to determine the configuration of the 61 ns isomer. Results show that the isomer is likely to be the product of a $\pi(h_{11/2})^2$ excitation with configuration $\{\nu 11/2^+[615] \otimes \pi 11/2^-[505] \otimes \pi 9/2^-[514]\}$, combining to $J^\pi = K^\pi = \frac{31}{2}^+$. This spin assignment would imply that the 453 keV γ-ray, de-exciting the isomer, is a stretched E2 transition. With these assumptions we can infer that the transition from the isomer has $\Delta K = 10$, and is thus 8 times K forbidden ($\nu = 8$), corresponding to a reduced hindrance of $f_\nu = \left(T^\gamma_{\frac{1}{2}}/T^{\rm Weis}_{\frac{1}{2}}\right)^{\frac{1}{\nu}} = 1.9$, where $T^\gamma_{\frac{1}{2}}$ is the partial γ-ray half-life and $T^{\rm Weis}_{\frac{1}{2}}$ is the Weisskopf single-particle estimate.

Although of very small magnitude, the implied value of reduced hindrance for ^{191}Os fits very well with an empirical logarithmic dependence of f_ν on the product of valence neutron and proton numbers for E2 transitions de-exciting 2 and 3-quasiparticle isomers with $\Delta K > 4$ [14–16], shown in figure 2. It is worth noting that the extra datum that ^{191}Os provides to the plot corresponds with the linearity that approaches $f_\nu = 1$ for closed-shell nuclei. This is consistent with the expectation that nearly magic nuclei are independent of effects from the K quantum number.

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