Investigation of Excited Levels in ^{193}Ir From the Beta Decay of ^{193}Os

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Received on 8 July, 2005

The excited states in ^{193}Ir populated by the β^- decay of ^{193}Os were investigated via γ-γ coincidence analysis. Three levels at 517, 563 and 621 keV, previsouly seen only in nuclear reaction studies, were observed in the present measurements; the 487 keV transition from the 849 keV level was identified, providing good evidence that the levels at 848.93 and 849.083 keV are the same. The level at 807 keV was positively identified through both the 449 and 668 keV transitions; also, there is evidence for four new levels at 880, 882, 890 and 986 keV, and several newly-found γ transitions were identified and placed in the decay scheme.

I. INTRODUCTION

The nucleus ^{193}Ir occupies a very interesting place in the nuclide table; whereas the ^{192}Os nucleus, which has one proton less than ^{193}Ir, has been successfully described as a prolate-deformed nucleus, the ^{194}Pt nucleus, with just one proton more than ^{193}Ir, shows oblate deformation [2]. The usual approach is to describe the ^{193}Ir nucleus as a triaxial rotor [2–5], but a recent study [6] has shown that it can be equally well described as a prolate rotor.

Moreover, while the ^{193}Ir nucleus has been recently thorougly studied through many different reactions, the last full examination of the β^- decay from ^{193}Os was made in 1972 [7], using Ge(Li) detectors with much lower detection efficiency than the presently-available HPGe detectors.

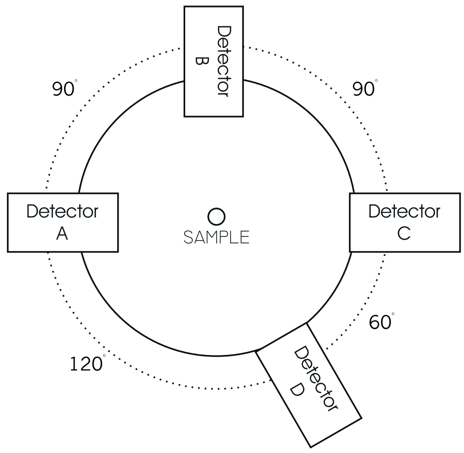

FIG. 1: Schematics of the planar detector setup used in the present measurements.

II. EXPERIMENTAL PROCEDURE

The present experiment was performed using the planar multidetector array system assembled at the Laboratrio do Acelerador Linear (LAL), in the Physics Institute of the So Paulo University [8]. For this experiment, four HPGe detectors, with volumes ranging from 50 to 120 cm^3, were used in coincidence mode; the detectors were placed around the sample as shown in Figure 1.

The coincidence electronics, schematically shown in Figure 2, check for a coincidence between two or more detectors within 200ns and, for each valid event, stores both time and energy information for each detector involved.

The samples were produced by irradiating 5mg of 99% enriched ^{192}Os for 5 minutes in the IEA-R1 reactor, under a neutron flux of about $10^{12} cm^{-2} \cdot s^{-1}$. Two sources were produced every week, and this procedure was repeated for two months, resulting in something around 1200h of counting.

The data obtained was analyzed using the BIDIM software [9], which allows the subtraction of accidental coincidences, through the use of a time gate, and bidimensional fitting of the peaks with compensation for the Compton remains of other peaks. It should be noticed that for the present analysis the events from all 6 detector pairs (*AB*, *AC*... *CD*, in the naming scheme used in Figure 1) were relocated, in order to equalize their energy calibration curves, and summed up to increase the overall detection efficiency – and, thus, the counting statistics.

Most of the γ-ray intensities were taken from a previous singles spectroscopy experiment [10, 11]; in the cases where the spectroscopy results didn't agree (within 2σ) with the reference values from [1], when the transition hadn't been seen in the spectroscopy experiment, and also for every new transition, $I(\gamma)$ was calculated from $\gamma-\gamma$ coincidence analysis by assuming that $\sum_{AB,AC...CD} W(\theta) \simeq k$, where k is constant for all transitions, regardless of their multipolarity and mixing ratio; this would be true if the detectors covered 4π – in the present case, the assumption was tested on several well-established transitions, and the values obtained were in excellent agreement with the expected ones. This way, if two gamma transitions γ_1 and γ_2 are in direct coincidence with a third one γ_3 (i.e., there are no intermediate transitions between γ_1 and γ_3 or between γ_2 and γ_3); then:

$$\frac{I(\gamma_1)}{I(\gamma_2)} = \frac{A(13)\cdot\varepsilon(23)}{A(23)\cdot\varepsilon(13)} \tag{1}$$

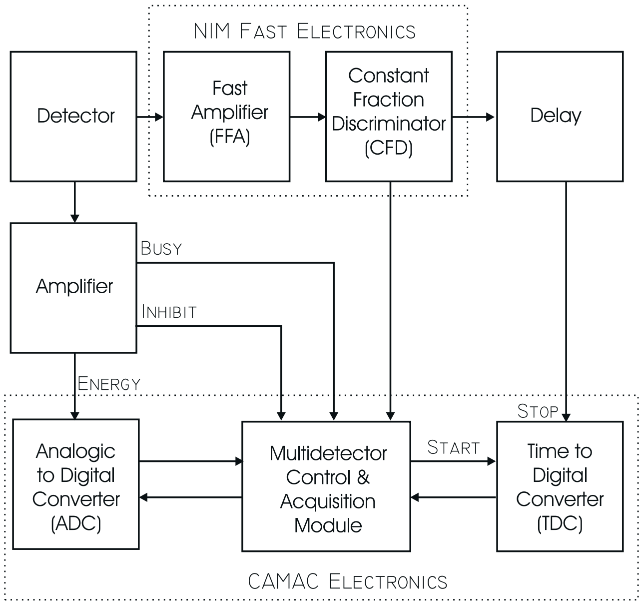

FIG. 2: Electronical setup used in the present experiment; everything except for the CAMAC Electronics is independent for each of the 4 detectors used.

where $A(ij)$ is the area of the coincidence photopeak for the pair $\gamma_i \times \gamma_j$ and $\varepsilon(ij)$ is the sum of the detection efficiencies of all six detector pairs for the cascade.

The internal conversion coefficients were calculated for the transitions with known multipolarity using the *HSICC* computer code; the levels' energies were calculated from a least-square fit of the energies of the related transitions using the *GTOL* package, and the β^- feedings were obtained by the same package from the intensity imbalance; the $log(ft)$ values were obtained using the *LOGFT* package and the absolute intensities were then obtained through the product of the absolute level feeding by the branching ratio of the transitions that depopulate that level; the documentation of all used packages can be found in reference [12].

III. RESULTS AND DISCUSSION

In the present experiment, 90 γ transitions were successfully identified; 2 of these transitions were known, but had no placement in the level scheme; 12 had never been seen in β^- decay experiments before, but were known from other reactions; and other 15 were completely new to the level scheme of ^{193}Ir. These results led to the verification of 4 levels only known from other reactions, as well as 4 completely new levels; Figure 3 shows simplified decay schemes for these new levels. also, the suspicion that the two levels at 848.9 and 849.1 keV were the same, reported in the ENSDF Adopted Levels for ^{193}Ir [1], was positively confirmed. On the other hand, four known transitions were not seen in this experiment; the 80 keV transition that depopulates the 80 keV isomer ($T_{1/2}$ ≈10d) wasn't seen because of its very long half-life; the 41 keV transition that depopulates the 180 keV level was below the energy threshold for this experiment (≈55 keV); the 486 keV transition that depopulates the level at 559 keV would only be coincident to the 73 keV transition, which is strongly contaminated by the 73.6 keV Ir $K_{\beta 1}$ X-Ray or to very weak transitions (I≤0.05%), so it couldn't be positively identified; finally, the 338 keV transition that depopulates the level at 1078 keV couldn't be identified either, but in fact this very weak transition has never been seen in a β^- decay experiment before, and is just assumed to be there because it was seen depopulating a level known to be populated by the β decay in the ^{191}Ir(nn,γ) experiment [1, 13].

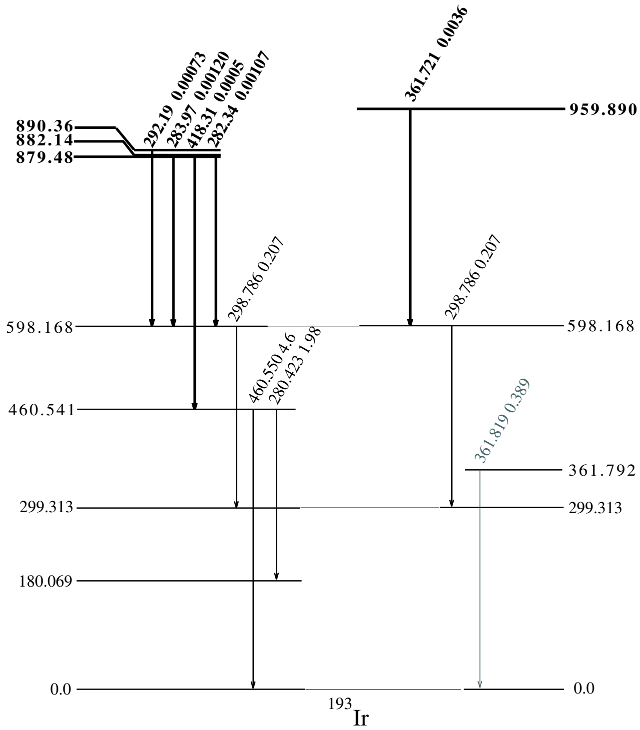

FIG. 3: Simplified decay scheme showing the newly-found levels; the new gamma-transitions and new level energies are shown in boldface.

The 27 radiations seen for the first time in this work, together with the 2 tentatively-positioned ones, are presented in Table I, together with their placement, as deduced from the present $\gamma-\gamma$ coincidence analysis. The placement of the transitions at 62 and 65 keV are considered tentative because of strong X-Ray contamination that prevent the definite assessment of the true coincidences.

A. The Previously Unplaced Transitions

The unplaced transition at 181 keV was successfully placed depopulating the 740 keV level; on the other hand, the unplaced transition at 65 keV was tentatively placed depopulating the 139 keV level, but this is a tricky placement because of the interference of the Ir $K_{\alpha 1}$ line at 64.9 keV.

E_γ (keV)	I_γ (%)	E_i (keV)	E_f (keV)
61.564(6)[a,t]	*nd*	138.902(3)	80.241(6)
64.838(6)[b,t]	<0.06[h]	138.902(3)	73.015(4)
154.751(24)[d]	0.0080(21)	516.523(23)[c]	361.792(4)
336.39(15)[d]	0.054(10)	516.523(23)[c]	180.069(3)
377.41(8)[d]	0.016(4)	516.523(23)[c]	138.902(3)
263.997(25)[d]	0.016(3)	563.348(15)[c]	299.313(8)
483.34(7)[d]	0.006(2)	563.348(15)[c]	80.241(6)
236.31 (4)[a]	0.017(3)	598.168(7)	361.792(4)
517.84(4)[a]	0.080(10)	598.168(7)	80.241(6)
263.02(15)[d]	0.0012(7)	621.01(4)[c]	357.784(8)
482.06(5)[d]	0.022(4)	621.01(4)[c]	138.902(3)
620.93(10)[d]	0.018(4)	621.01(4)[c]	0
96.969(15)[a]	0.009(2)	695.175(6)	598.168(7)
354.25(12)[a]	0.0023(13)	712.172(5)	357.784(8)
176.907(16)[a]	<0.029	740.258(8)	563.348(15)[c]
181.38(4)[b]	0.0040(11)	740.258(8)	559.224(7)
382.63(15)[a]	0.0017(10)	740.258(8)	357.784(8)
601.89(18)[d]	0.0063(9)	740.258(8)	138.902(3)
449.16(6)[d]	0.007(3)	806.96(5)[g]	357.784(8)
668.09(9)[f]	0.016(2)	806.96(5)[g]	138.902(3)
487.22(11)[d]	0.0053(12)	849.127(22)	361.792(4)
491.26(8)[a]	0.0045(18)	849.127(22)	357.784(8)
253.08(8)[a]	<0.043	874.273(11)	621.01(4)[c]
314.93(5)[a]	0.050(10)	874.273(11)	559.224(7)
282.34(9)[a]	0.025(3)	879.48(6)[e]	598.168(7)
418.31(7)[a]	0.012(7)	879.48(6)[e]	460.541(4)
283.97(7)[a]	0.028(3)	882.14(7)[e]	598.168(7)
292.19(7)[a]	0.0170(24)	890.36(7)[e]	598.168(7)
361.51(3)[a]	0.083(7)	959.68(18)[e]	598.168(7)

TABLE I: Gamma radiations seen or placed for the first time in this experiment; I_γ is the relative gamma-ray intensity (the intensity of the gamma-ray at 460.550 keV is considered as 100%); E_i and E_f are the excitation energies of the initial and final levels for that transition, respectively.

[a] New transition;

[b] Radiation previously known, but unplaced in ENSDF [1];

[c] Level previously known only from other reactions;

[d] Transition previously known only from other reactions;

[e] New level;

[f] Transition considered uncertain in ENSDF [1];

[g] Level considered uncertain in ENSDF [1];

[h] Intensity value from ENSDF [1];

[i] Intensity value couldn't be independently obtained from experimental data, so a limit was estimated using ENSDF adopted branching ratio [1];

[t] Tentative placement;

nd The intensity of this transition could not be determined.

B. The 849 keV Level

In the ENSDF Adopted Levels for ^{193}Ir [1], there was the suspicion that the two levels at 848.93 keV and 849.083 keV could be the same, but as the latter was seen only in the ^{191}Ir(nn,γ) experiment [13], which only studied $E_\gamma < 700$ keV, and the former was only known to be depopulated by transitions above that energy (710, 776 and 849 keV), if the two transitions found to depopulate the 848.93 keV level in the (nn,γ) experiment were too weak in comparison to the other ones, they could have remained unseen in the other experiments and thus the levels couldn't be positively identified to be the same.

In this experiment, though, the 487 keV transition was identified together with the 710, 777 and 849 keV transitions, and their energies confirm that they come from the same level at 849 keV. On the other hand, though, the transition with 389 keV, expected to be stronger than the 487 keV one, was not seen; one possible reason for this is that it could have been masked by the very strong ($I_\gamma = 31.5\%$) 387 keV transition that depopulates the 461 keV level.

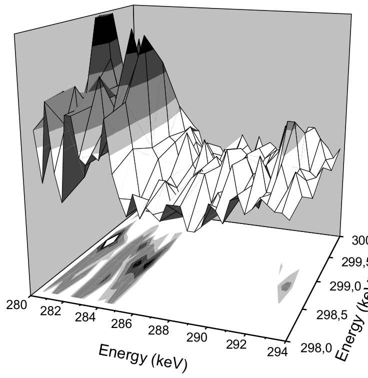

FIG. 4: Excerpt of the coincidence spectrum zoomed in the coincidences of the newly-found 282, 284 and 292 keV transitions with the 299 keV transition that depopulates the 598 keV level.

C. Levels Previously Seen Only in Other Reactions

The levels at 517, 563 and 621 keV, known only from other reactions [1], were positively identified in the present experiment.

The level at 807 keV, reported as uncertain in the last compilation [1], was successfully seen, not only through the 668 keV transition (also cited as uncertain the the compilation), but also through another transition at 449 keV.

D. New Levels

A new triplet was found with excitation energies of 879, 882 and 890 keV; Figure 4 shows an excerpt of the bidimensional spectrum zoomed in the three coincidences that defined these levels, where the 282, 284 and 292 keV transitions can be seen in coincidence with the 299 keV transition which is the strongest transition to depopulate the 598 keV level, thus suggesting the placement of the three transitions populating that level, leading to the three new levels; the level at 879 keV was also confirmed by the placement of a new 418 keV transition, which was found in coincidence with the 461 keV transition that depopulates the level at 461 keV, which is very well established in the β^- decay scheme of ^{193}Os.

In addition to that, a new transition with 362 keV was also found in coincidence with the 299 keV transition, as shown in Figure 5, which led to the proposition of a new level at 956 keV.

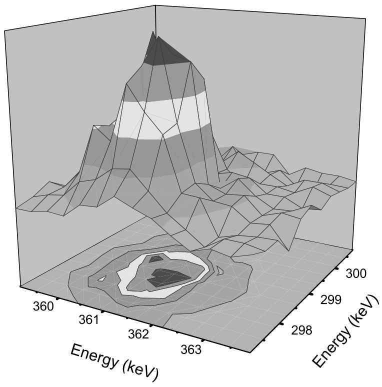

FIG. 5: Excerpt of the coincidence spectrum zoomed in the coincidences of the newly-found 362 keV transition with the 299 keV transition that depopulates the 598 keV level.

IV. CONCLUSIONS

The present experiment extended the knowledge about the ^{193}Ir nucleus by adding 8 new levels and 27 new transitions to the scheme of the β^- decay of ^{193}Os. Two transitions left unplaced in the last compilation were placed in the decay scheme, and two levels were shown to be the same.

Acknowledgments

The authors would like to thank the Laboratorio do Acelerador Linear (LAL/IFUSP) for the experimental facilities.

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