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PROPOSAL TO THE ISOLDE COMMITTEE

THE SEARCH FOR M3 TRANSITIONS IN ^{183}Pt AND ^{181}Os

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SUMMARY: We propose to search for the M3 transition linking the isomeric and ground states in ^{183}Pt and ^{181}Os by detecting the internal conversion electrons with high energy-resolution. This experiment would allow us:
(i) to extract the B(M3) transition probabilities; their comparison with the B(M3) value in ^{184}Au would be useful to test the neutron configurations proposed to describe the isomeric and ground states of ^{184}Au,
(ii) to locate the isomeric state with respect to the ground state in ^{181}Os, and
(iii) to complement the rare information on M3 transitions (about thirty M3 transitions are known in the table of isotopes and among them only nine in odd nuclei).
The beam time requested is ten shifts.

1. INTRODUCTION

At the present time, the existence of an isomeric state in ^{184}Au remains puzzling. Even though the experimental data are clear — the M3 transition linking the isomeric and ground states has been observed by the NICOLE group at ISOLDE[1]) and then confirmed at ISOCELE[2]) — the interpretation proposed for these two states may not explain the presence of an isomeric state. Indeed, from the neutron (ν) and proton (π) states observed at low energy in the odd nuclei close to ^{184}Au, the most probable $\nu \otimes \pi$ configurations for ^{184m}Au ($I^{\pi} = 2^{+}$ or 3^{+}) and ^{184g}Au ($I^{\pi} = 5^{+}$ or 6^{+}) are $\nu\frac{1}{2}[521]\otimes\pi h_{9/2}$ and $\nu\frac{7}{2}[514]\otimes\pi h_{9/2}$ respectively. But, the $I^{\pi} = 4^{+}$, 5^{+} and 6^{+} states arising from the $\nu\frac{7}{2}[514]\otimes\pi h_{9/2}$ configuration are expected to be located within a few keV; this would give rise to low angular momentum transitions by-passing the isomeric transition.

Our purpose is to test the neutron configuration proposed to describe the isomeric and ground states of ^{184}Au by comparing the transition probability B(M3) in ^{184}Au to what is found in odd neighbouring nuclei. The $\frac{1}{2}[521]\rightarrow\frac{7}{2}[514]$ M3 transition has only been observed in ^{179}W, so we propose to search for such a transition in ^{183}Pt and ^{181}Os, by detecting the internal conversion electrons with high energy-resolution. Moreover, it is worth noting that M3 transitions are very rare: about thirty are known in the literature and among them only nine in odd nuclei. Thus, in addition to shed some light on the structure of the isomeric and ground states of ^{184}Au, this experiment will allow us:

(i) to locate the isomeric state with respect to the ground state in ^{181}Os,

(ii) to point out rare phenomena such as M3 transitions.

2. SCIENTIFIC MOTIVATIONS

The absolute γ-ray transition probability between nuclear states depends on the multipolarity of the transition and on the wave functions of the states linked by the transition. Measuring transition probabilities is therefore a powerful mean of investigating the structure of nuclear states. This has been often used to characterize the states observed in the deformed odd nuclei[3]). Moreover, it has been shown that transitions between the same particle states in odd and doubly-odd nuclei usually have similar Weisskopf retardation factors (F_W) [ref.[4])]. This rule has been established from the analysis of low-multipolarity transitions, namely E1, M1 and E2 transitions. This seems to be true also for the M3 transitions, though the comparison between odd and doubly-odd nuclei is not often feasible because of the scarcity of M3 transitions. For instance, we can note that, for the neutron transition $\nu g_{\frac{7}{2}}\rightarrow\nu s_{\frac{1}{2}}$ in ^{113}Sn and ^{112}In as well as for the proton transition $\pi\frac{1}{2}[411]\rightarrow\pi\frac{7}{2}[404]$ in ^{181}Ta and ^{166}Lu, the F_W factors are slightly smaller in the odd than in the odd-odd nuclei. On the other hand, the F_W value obtained for the M3 transition connecting the isomeric and ground states is much weaker in ^{184}Au than the one found for the $\frac{1}{2}[521]\rightarrow\frac{7}{2}[514]$ transition in ^{179}W (see table 1).

Table 1

Nucleus	B(M3)(μ^2fm^4)	F_W(M3)	F_W(odd)/F_W(odd-odd)
^{112}In	5.2	170	0.2
^{113}Sn	27	33	
^{166}Lu	108	14	0.3
^{181}Ta	406	4.2	
^{184}Au	~33	~ 52	~ 35
^{179}W	0.92	1800	

Do we have to conclude that:
(i) the hindrance of the $\frac{1}{2}$[521]→$\frac{7}{2}$[514] K-allowed M3 transition is especially high in ^{179}W,
(ii) or the configurations proposed for the ground and isomeric states in ^{184}Au are not correct?

^{179}W is the only odd nucleus in which the $\frac{1}{2}$[521]→$\frac{7}{2}$[514] M3 transition has been observed. Thus, in order to answer the questions posed above, we propose an experiment to measure the $\frac{1}{2}$[521]→$\frac{7}{2}$[514] transition probability in other odd nuclei close to ^{184}Au. In addition such an experiment would provide new evidence of M3 transitions and then complement the rare information available on these transitions.

Fig. 1 shows the systematics of the intrinsic states observed in the N = 105 and N = 107 isotones. The M3 transitions found in these nuclei as well as the F_W(M3) factors are indicated in fig. 1. In the N = 107 isotones, the M3 transition observed in ^{177}Yb and ^{179}Hf connects the $\frac{1}{2}$[510] state to the $\frac{7}{2}$[514] state. But in the heavier isotones, no M3 transition is observed because of the energy locations of the intrinsic states. In the N = 105 isotones, the $\frac{1}{2}$[510]→$\frac{7}{2}$[514] M3 transition has been pointed out in ^{175}Yb, but in ^{179}W the $\frac{1}{2}$[510] state does not decay to the $\frac{7}{2}$[514] level because its deexcitation to the $\frac{5}{2}$[512] level and to the states of the $\frac{1}{2}$[521] band is possible. On the other hand, the M3 transition between the $\frac{1}{2}$[521] and $\frac{7}{2}$[514] states is observed in ^{179}W and fig. 1 shows that such a transition can exist in ^{183}Pt and ^{181}Os.

3. PROPOSED EXPERIMENT

We propose to determine the probability of the M3 transition between the isomeric and ground states in ^{183}Pt and ^{181}Os. This implies to know the half life of the isomeric state and the absolute intensity of the transition. Since the expected energy of these transitions in ^{183}Pt and ^{181}Os is low (see Sect. 4) and the values of the M3 conversion coefficients are high, measuring the internal conversion electrons is the best way to identify these isomeric transitions and to determine their intensities. This requires an apparatus to detect low-energy electrons with resolution high enough to separate the L-lines and even the M-lines in order to determine the multipolarity of the transition. Systems using cooled Si(Li) detectors have good detection efficiency but, at low energy, they do not have resolution high enough to perform the experiment we propose. On the contrary, using magnetic spectrographs or spectrometers, the energy resolution is improved but, of course, to the detriment of detection efficiency. In that way, in order to detect very low-energy conversion electrons with high resolution, our group has designed a 180° magnetic spectrograph, coupled to an electron preacceleration system and to a fast mechanical tape transport system associated to a decelerating lens [5]). This experimental setup is then well suitable for performing the experiment we propose. Installed at first at the on-line isotope separator ISOCELE, it has been modified to work on line with the ISOLDE separator. In this way, the radioactive ions are slowed down from 60 kV to around 500 V before collection on aluminum deposits which have been atomized on an insulating tape. This allows us to preserve, at low energy, high resolution detection ($\Delta p/p \sim 10^{-3}$). The radioactive source is then moved into the spectrograph and a high voltage (-10 kV) is applied to accelerate the conversion electrons emitted by the source in order to allow the very low-energy electrons to be detected by the photographic film. With a magnetic field of 5.0 10^{-3} T, an energy range from 2.5 to 85 keV is covered. It is worth noting that the stability of the magnetic field (better than 2 10^{-4} for a run of 72 h) enables measurements to be performed over long periods without any deterioration of resolution.

4. FEASIBILITY OF THE EXPERIMENT

4.1. ^{183}Pt

The half life and the energy of the isomeric state are known: $T_{\frac{1}{2}}$ = 43 s and E = 34.3 keV[6]). Using for this transition the retardation factors obtained for the M3 transitions in ^{184}Au and in ^{179}W, we estimate that the intensity of the isomeric transition can vary from 0.4% to 64%. Taking the yield of ^{183}Hg given in the ISOLDE users' guide (4.5 10^7 atoms/s) and taking into account the half lives of the elements of the radioactive chain issued from ^{183}Hg, the feeding of the isomeric state of ^{183}Pt, the internal conversion coefficient of the 34.3 keV M3 transition, the transmission of the spectrograph and the detection efficiency of the film, we have estimated that a measurement lasting 24 h using the following cycle ($t_{collection}$ = 100 s, $t_{waiting}$ = 60 s and $t_{counting}$ = 160 s) will allow us to point out the M3 transition provided that its intensity is $\geq$ 0.4%.

4.2. ^{181}Os

Little information is available on the low-spin levels in ^{181}Os. The half life of the $\frac{1}{2}$[521] state has been measured ($T_{\frac{1}{2}}$ = 105 m) as well as that of the $\frac{7}{2}$[514] state ($T_{\frac{1}{2}}$ = 2.7 m) [ref.[7])], but the relative location of these two states has not yet been determined. However, the $T_{\frac{1}{2}}$ = 105 m ^{181}Os decay has been studied extensively and, from consideration of limits of detection and calculated branching ratios, the authors have estimated that the ground state is probably the $T_{\frac{1}{2}}$ = 105 m $\frac{1}{2}$[521] state[8]).

Fig. 2 shows the expected intensity for the M3 reduced transition probability B(M3) for various values of the transition energy. We have estimated that, with the yield given by the ISOLDE users' guide for ^{181}Hg (7 10^5 atoms/s), we can observe the isomeric transition provided its intensity is $\geq 4\%$ by measuring the conversion electrons during 48 h using the following cycle: $t_{collection} = t_{counting}$ = 900 s and no waiting time.

Therefore this measurement will allow us:
- to determine not only the B(M3) transition probability but also the energy of the isomeric state, if we can observe the isomeric transition,
- and in the case we cannot, to define limits of B(M3) versus E_γ(IT) (see fig. 2).

5. BEAM TIME REQUEST

The detection of the internal conversion electrons cannot be verified immediately because they are recorded using photographic films. It is therefore necessary to test the performance of the system immediately prior to the experiment. Such a test should be done with a high-yielded isotope ($A \geq 187$) and would take a few hours to complete. The measurement itself would require three shifts for ^{183}Pt and six shifts for ^{181}Os. Therefore, a total of ten shifts is requested. We have to mention that the estimation of the time needed has been made using the yields given in the ISOLDE users' guide, which are for 1 μA, despite of the fact that the present molten lead target stands 0.5 μA. But we are working on an improved version that should stand 3 μA, in collaboration with the ISOLDE separator group.

6. REFERENCES

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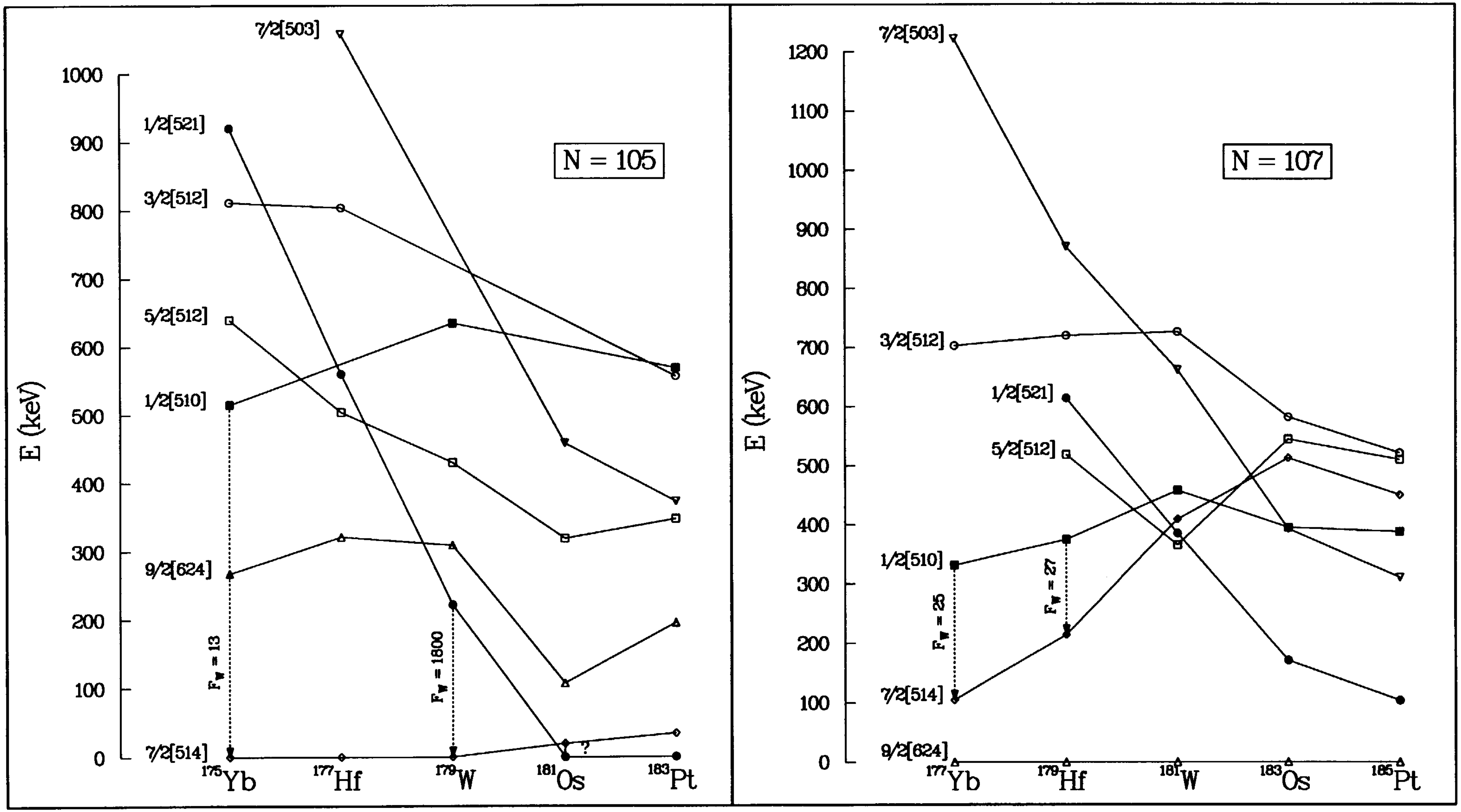

Fig. 1. Systematics of the intrinsic states through the N=105 and N=107 isotones. The relative position of the isomeric and ground states in ^{181}Os is not known[7,8]).

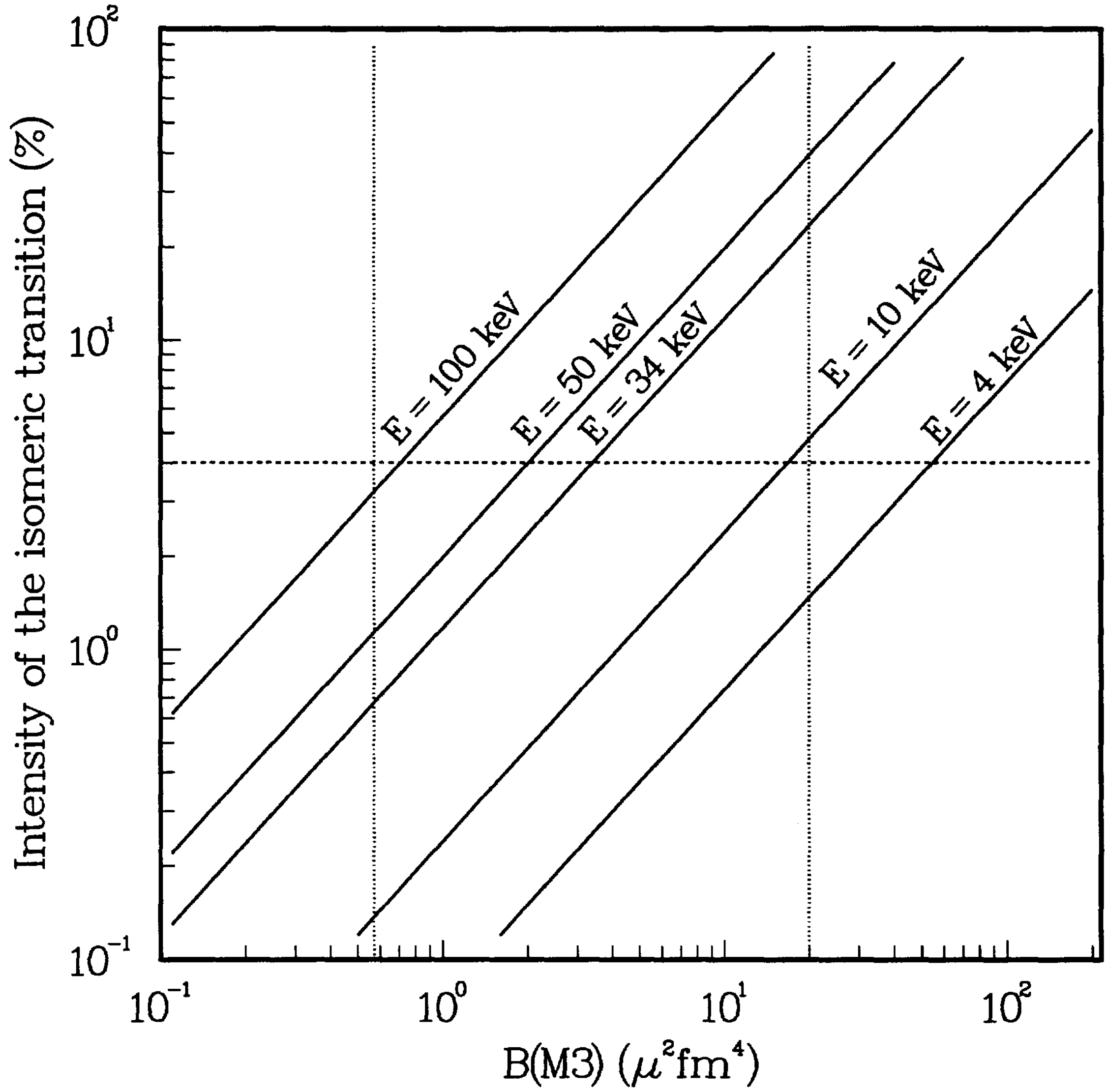

Fig. 2. Intensity of the isomeric transition calculated versus B(M3) for ^{181}Os. The vertical dotted lines indicate the B(M3) values obtained for ^{181}Os assuming the same F_W(M3) factors than those found for the isomeric transition in ^{184}Au (F_W(M3,^{184}Au) = 52 $\Rightarrow$ B(M3,^{181}Os) = 20) and in ^{179}W (F_W(M3,^{179}W) = 1800 $\Rightarrow$ B(M3,^{181}Os) = 0.57).