TABLE II. Comparison of the two $2^{+\prime}$ states of Kumar and Baranger with experimental results. Values of $B(E2; 2^+ \rightarrow 2^{+\prime})$ were derived from $B(E2; 0^+ \rightarrow 2^{+\prime})$, using the branching ratios of Ref. 4.

	$2_a^{+\prime}$	$2_b^{+\prime}$	Expt.
	^{184}W		
$B(E2; 0^+ \rightarrow 2^{+\prime})$	0.085	0.135	0.138
$B(E2; 2^+ \rightarrow 2^{+\prime})$	0.176	0.007	0.050
$g(2^{+\prime})$	0.736	-1.097	0.1
	^{186}W		
$B(E2; 0^+ \rightarrow 2^{+\prime})$	0.154	0.083	0.139
$B(E2; 2^+ \rightarrow 2^{+\prime})$	0.302	0.002	0.064
$g(2^{+\prime})$	1.053	-1.735	1.3

which implies that its average deformation is small. This is in contrast with ^{186}W where the $2^{+\prime}$ state is well deformed. Two-neutron-transfer reactions have previously provided evidence of the coexistence of nearly spherical and deformed nuclear states in regions of the periodic table where a rapid shape transition occurs. Excited states of such small deformation have not previously been found in permanently deformed nuclei.

The calculations of Kumar and Baranger fit the trend of the present data quite well. For the tungsten isotopes, this calculation predicts a strong coupling between the β and γ bands. In this model, this is the source of the reduced value of $q(2^{+\prime})$. This strong coupling is also supported by the large $B(E2)$ values connecting the β and γ bands in ^{184}W.

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High-Spin States in ^{183}Ir and ^{185}Ir Nuclei: Is the Breaking of a Few Pairs of Nucleons Responsible for the Backbending Effect in the Osmium Region?*

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High-spin levels of the rotation-aligned bands built on the $h_{9/2}$ subshell in ^{183}Ir and ^{185}Ir have been populated by $(\alpha, 6n\gamma)$ and $(\alpha, 4n\gamma)$ reactions. In ^{183}Ir a rapid increase in the apparent moment of inertia has been observed at high spins. The implication of this result for the interpretation of backbending phenomena in even nuclei in this mass region is discussed.

The anomalies exhibited by the nuclear moment of inertia of many deformed nuclei at high rotational velocities has been described by two competing microscopic models: the Coriolis antipairing[1,2] and the rotational alignment model.[3] Although the possibility that both effects contribute to the backbending phenomena cannot be excluded,[4] it seems now that the decisive contribution is due to the Coriolis decoupling of one pair of nucleons (the rotation alignment). This decoupling is expected for the lowest Ω orbitals originating from spherical subshells of high angular momentum j.

Investigations of rotational bands in the neighboring odd-A nuclei, where the corresponding orbitals are blocked, have shown that the backbending of even nuclei in the rare-earth region is due to the decoupling of an $i_{13/2}$ neutron pair[5,6] *or* to the decoupling of an $h_{9/2}$ proton pair.[7,8] The situation is not so clear in the transitional osmium region. In ^{182}Os the backbending effect has been attributed to the decoupling of an $i_{13/2}$ neutron pair although the Fermi surface is located in the vicinity of $\Omega=\frac{9}{2}$, or to the alignment of an $h_{9/2}$ proton pair.[9,10] The results of Neskakis *et al.*[11] seem to confirm the latter hypothesis: The $i_{13/2}$ mixed-positive-parity band in ^{181}Os shows backbending but not the $h_{9/2}$ decoupled band in ^{181}Re. However it was noted by these authors and by Bernthal *et al.*,[12] for the ^{180}W nucleus, that more than one effect should perhaps be considered in order to explain the backbending in this region.

The rotation-aligned band built on the $h_{9/2}$ subshell has been previously identified at a rather low excitation energy in odd-proton ^{189,187}Ir isotopes.[13] Bearing in mind the importance of the behavior of this band for the understanding of the backbending phenomenon in even Os and Pt nuclei, we have carried out an in-beam γ-spectroscopic study[14] of the ^{183}Ir and ^{185}Ir isotopes.

The experiments were performed with an α-particle beam from the Grenoble variable-energy cyclotron, by means of the reactions ^{185}Re(α, $6n\gamma$)^{183}Ir, ^{185}Re(α, $4n\gamma$)^{185}Ir, and ^{187}Re(α, $6n\gamma$)^{185}Ir. The projectile energies used were 72 and 80 MeV for an (α, $6n$) reaction and ranged from 41 to 56 MeV for the (α, $4n$) reaction. Figure 1 shows the partial level schemes established on the basis of the excitation functions, angular distribution of the γ rays, and γ-γ time-coincidence spectra.

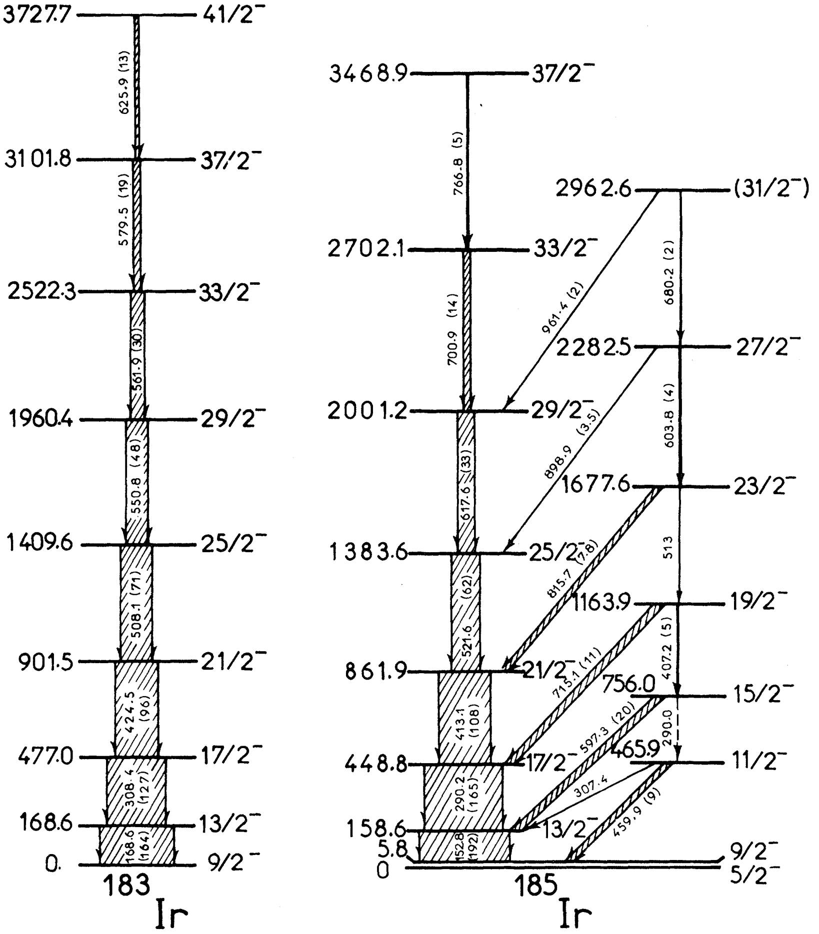

FIG. 1. Partial level schemes for ^{183}Ir and ^{185}Ir.

The ^{185}Ir *nucleus.*—The spin of the ground state has been established[15] as $\frac{5}{2}$ and interpreted as the lowest member of the rotational band built on the $\frac{1}{2}^-(541)$ Nilsson state. Recently the low-spin levels have been studied by the radioactive decay of ^{185}Pt.[16] In our study, the assignment of γ transitions to ^{185}Ir was made on the basis of the excitation functions in the $(\alpha, 4n)$ reaction. Negative-parity levels with energies up to 3.5 MeV and spins up to $\frac{37}{2}$ were observed (cf. Fig. 1). They can be interpreted as a part of the system of rotational levels built on the deformed orbitals originating from the $h_{9/2}$ and $f_{7/2}$ spherical subshells, strongly coupled by the Coriolis interaction.[17]

The ^{183}Ir *nucleus.*—The system of the rotational levels connected by the stretched $E2$ transitions observed in ^{183}Ir is interpreted as the decoupled rotational band built on the $\frac{1}{2}^-(541)$ proton state, as in the $^{185-189}$Ir isotopes. According to the Nilsson scheme, the following single-particle states are expected for $Z=77$: $\frac{5}{2}^+(402)$, $\frac{9}{2}^-(514)$, and $\frac{1}{2}^-(541)$. Comparison of the rotational bands built on these states can be found, e.g., in Ref. 11 (^{181}Re); and one can easily see that only the band built on the $\frac{1}{2}^-(541)$ state is similar to that observed in ^{183}Ir.

This interpretation can be further supported by the striking regularity of the dependence of $[E(I+2)-E(I)]/[E(I-j+2)-E(I-j)]$ versus the mass number A for the $h_{9/2}$ bands in the odd-A Ir isotopes (Fig. 2) where the values in the denominator are taken for the even Os core. Therefore, one can expect that the lowest level of this band has the spin and parity value of $\frac{9}{2}^-$ as in the ^{187}Ir and ^{189}Ir isotopes.

To our knowledge, no data on the excited levels in ^{183}Ir were available prior to our study. The decay of this isotope to ^{183}Os was investigated recently[19] and spin $\frac{5}{2}$ with the Nilsson quantum numbers $\frac{5}{2}^+(402)$ was proposed for the ground state. However, the strong direct feeding of the well-established $\frac{9}{2}^-$ state belonging to the $K=\frac{1}{2}$ band in ^{183}Os suggests a low-K value ($\frac{1}{2}$ or $\frac{3}{2}$) and spin between $\frac{7}{2}$ and $\frac{11}{2}$ for the ground state of the parent isotope. These facts are in agreement with the assumption that the $\frac{9}{2}^-$ state of the $\frac{1}{2}^-(541)$ rotational band observed in the present work is the ground state of the ^{183}Ir nucleus.

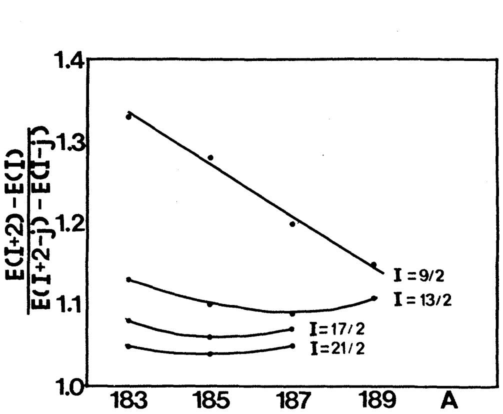

FIG. 2. Systematics of the ratio of the energies of the $E2$ transitions in the $\frac{1}{2}^-(541)$ rotational band to the corresponding $E2$ transitions in the even osmium core.

Comparison between values of the inertial parameter $\hbar^2/2J$, simply deduced from the energy difference $E_{13/2}-E_{9/2}$, shows that ^{185}Ir appears to be the most deformed iridium isotope. For ^{183}Ir this parameter is comparable to the one observed in ^{187}Ir.

The backbending behaviors.—The plots of $2J/\hbar^2$ vs $\hbar^2\omega^2$ for the rotational bands observed in ^{183}Ir and ^{185}Ir (this work), in ^{182,184}Os (Ref. 11), and ^{184,186}Pt (Refs. 19, 20) are shown in Fig. 3. To obtain the rotational frequency ω and the moment of inertia J, the following formulas were used[19]:

$$\frac{2J}{\hbar^2}=\frac{4I+6}{E(I+2)-E(I)},\quad \hbar^2\omega^2=4(I^2+3I+3)\left(\frac{\hbar^2}{2J}\right)^2.$$

For the decoupled bands in the Ir isotopes the angular momentum I was replaced by $I-j$, where j is the angular momentum of the subshell. This approach, suggested by the rotational alignment model, is a good approximation even if the de-

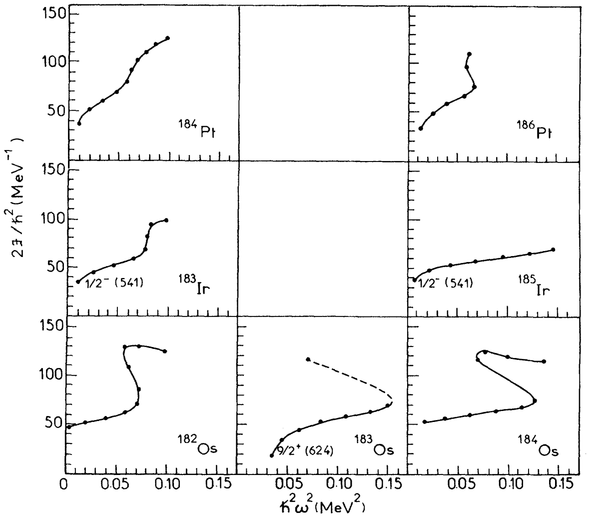

FIG. 3. Moment of inertia as a function of the square of the rotational angular velocity for ^{183,185}Ir, ^{182,184}Os, and ^{184,186}Pt.

coupling is not complete.

The clearly seen upbending of the ground-state band in ^{183}Ir is—as far as we know—the first case of this effect observed for the rotational band built on a $\frac{1}{2}^-(541)$ proton orbital. Thus, the backbending of the core is not hindered by the blocking of the $\Omega=\frac{1}{2}$ member of the $h_{9/2}$ proton subshell, which suggests that the backbending in ^{182}Os is not due to the $h_{9/2}$ protons *only*.

The similarity of the backbending behaviors, on the one hand between ^{182}Os and ^{183}Ir, on the other hand between ^{184}Os and ^{185}Ir, is very striking. In ^{182}Os, the critical angular momentum is $I=10$, the same as the critical value of $I-j$ for ^{183}Ir, with similar rotational frequencies ($\hbar^2\omega^2=0.072$ and 0.078, respectively). In contrast, in ^{184}Os the critical angular momentum is $I=14$ at $\hbar^2\omega^2=0.13$, and the $h_{9/2}$ band in ^{185}Ir does not show any backbending up to $I-j=14$ and $\hbar^2\omega^2=0.15$ (our attempts to find the $\frac{41}{2}^- \rightarrow \frac{37}{2}^-$ transition were unsuccessful). The difference in behavior of ^{183}Ir and ^{185}Ir supports the assumption that more than one orbital should be considered in order to explain the backbending effect in the osmium region. One can expect that the greatest contribution arises from the states whose rotational bands show this effect at the highest values of the rotational frequency. The states which do not contribute, such as $\frac{1}{2}^-(521)_n\ p_{3/2}$ and $\frac{7}{2}^-(514)_n\ f_{7/2}$ in ^{181}Os, and $\frac{5}{2}^+(402)_p\ d_{5/2}$ and $\frac{9}{2}^-(514)_p\ h_{11/2}$ in ^{181}Re (see Ref. 9), have critical $\hbar^2\omega^2$ values (0.05, 0.08, 0.07, and 0.075, respectively) of the same order as the ground-state band in ^{182}Os (0.072). On the contrary, high critical values are observed for the orbitals arising from $(h_{9/2})_p$ [$\hbar^2\omega^2 \geqslant 0.15$ in ^{185}Ir, $\geqslant 0.12$ in ^{181}Re] and $(i_{13/2})_n$ ($\hbar^2\omega^2=0.15$ in ^{183}Os). Therefore, it seems justified to assume (1) that none of the orbitals near the Fermi energy contributes uniquely to the backbending in the osmium region; (2) that the major contributions arise from the $(h_{9/2})_p$ and probably from the $(i_{13/2})_n$ subshells; and (3) that the contribution of these different subshells strongly depends on the deformation and/or on their location relative to the Fermi level.

The hypothesis of a simultaneous breaking of a few nucleon pairs needs, of course, further verification. The observation, or not, of the backbending in the $(h_{9/2})_p+(i_{13/2})_n$ band in the odd-odd ^{184}Ir nucleus could be a good test of this hypothesis.

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