PROPERTIES OF THE LOW-LYING LEVELS IN THE EVEN Pt AND Os NUCLEI

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In this contribution we present the status\textsuperscript{1-4} of the analysis of our results from the study of low-lying level characteristics in a series of even neutron-deficient platinum and osmium nuclei (182 ≤ A ≤ 192).

This work has been particularly favoured by the technique used for the separation of these isotopes. A molten lead target is bombarded by a 600 MeV proton beam, and the Hg nuclei produced are separated by the ISOLDE on-line facility at CERN\textsuperscript{5}). The nuclear spectroscopic equipment at our disposal consisted of Ge(Li) and Si(Li) detectors, beta spectrometers, fast and delayed coincidence systems, including a double-lens electron-electron magnetic spectrometer, a PDP-9 computer, etc.

The availability of nuclei far from the β stability line is very favourable in the search for systematic trends in the properties of nuclei between the pure rotational and magic regions. The study of this transitional region is already the subject of several theoretical works\textsuperscript{6-8}) intended to extend the basic models and to establish their common features,

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as will be mentioned in the discussion. It should be emphasized that some of our interpretations are tentative. Some of these will be checked by angular correlation measurements. Nevertheless it seems useful to present even such preliminary data at this stage.

We have particularly searched for:

- the existence or non-existence of various bands previously proposed\(^9\)\(^-\)\(^12\);

- the inversion of the relative positions of collective low-energy levels;

- the variation in the energy of levels of the same characteristics;

- major variations in the value of B(E2) branching ratios.

Some results obtained by other groups\(^13\)\(^-\)\(^25\) have been used or confirmed, in particular those from heavy ion reactions concerning the fundamental band.

Decay schemes have been established mainly on the basis of single gamma spectra, gamma-gamma coincidences [Ge(Li)-Ge(Li)], and conversion electron data, and by using energy sum relations. In the interpretation of internal conversion data, highly converted transitions between even parity states with the same angular momentum have been assumed to be E0 or E0+E2+M1. We have also measured some half-lives of the 2\(^+\) levels (Table 1). Values for B(E2, 2\(^+\) \rightarrow 0\(^+\)) have been deduced, and, when possible, compared with those calculated by Kumar and Baranger\(^6b\)). Some results were also obtained at Dubna\(^26\) for \(^{182}\)Os and \(^{184}\)Os (Figs. 1 and 2).

In Fig. 3 we present the results for low-lying levels of Pt nuclei. A similar study is in progress\(^27\) on levels in \(^{182}\),\(^{184}\),\(^{186}\)O. From Fig. 3 and Table 2 we can recognize the smooth variation in the energies for the fundamental band [as previously observed for some of these nuclides\(^14\)\(^-\)\(^16\)], and also the almost constant energy of the 2\(^2\) level\(^23\),\(^24\). Some new features, which are perhaps significant, should be pointed out:

- The collective character is apparent for the 2\(^+\) level from the measured B(E2, 2\(^+\) \rightarrow 0\(^+\)) in the Os and Pt nuclei (Figs. 1 and 2).

- The 0\(^2\) state seems to show a very low minimum energy at A=186 and an apparent maximum for A=194 \(^13\),\(^17\)\(^-\)\(^19\),\(^27\).


- Some $2^+$ levels (and in some cases $4^+$) de-excite to the $2_1^+$ and $4_1^+$ levels of the fundamental band by E0+E2+(M1) transitions (with a strong E0 component) and preferentially to the $0_2^+$ (see Table 3). This is a characteristic of a $\beta$ band in deformed nuclei.

- The behaviour of the $3_1^+$ level and of the $4_2^+$ (when known) is similar to the behaviour of the $2_2^+$ level. This, and the fact that the $4_2^+$ and $3_1^+$ de-excite preferentially to the $2_2^+$, is characteristic of a $\gamma$ band in deformed nuclei.

- The relative branching ratio $B(E2, 2_2^+ \rightarrow 0_1^+)/B(E2, 2_2^+ \rightarrow 2_1^+)$ increases from $\sim 10^{-5}$ to 0.1 for $196 < A < 184$ (see Fig. 4). [The vibrational value is 0.0, the rotational value 0.7 (Alaga rule).]

- If one applies the usual terms of the vibrational model, we notice that the two- and three-phonon multiplets are less mixed for $^{186}$Pt than for other masses. (This is the mass showing the minimum energy for the $0_2^+$ level.) We also notice that the $0_2^+$ and $4_1^+$ levels are closer together than $0_2^+$ and $2_1^+$ levels. Present experimental results$^{14, 18-25}$ do not allow us to determine the nature of the second $0^+$ levels. (We have some candidates for $0_1^+$ levels which are still not placed in the decay schemes.) We have observed many highly converted transitions (E0+E2+M1?) which have not been placed in the schemes. These possibly result from strong coupling between $\beta$ and $\gamma$ bands, or of two-phonon $\beta-\gamma$ states.

- Finally the $3^-$ level, which is characteristic of octupole vibration, has a rather constant energy ($\approx 1400$ keV).

Three principal conclusions may be drawn:

- Low-lying levels in Pt nuclei seem to be organized in bands, and the $\beta$ band-head is strongly mixed with the ground band.

- The energy of the levels of the proposed $\beta$ and $\gamma$ bands present minima for masses $A=186-190$.

- A marked variation of the energy and of the relative positions of the levels takes place between masses 186-190. As these two last points refer to the same masses, they are perhaps correlated.
Among the theoretical interpretations proposed for the transitional nuclei, we would like to mention three which propose explanations for some of the experimental results we have found. In the model of Kumar and Baranger\(^6\) (microscopic calculation of the Bohr-Mottelson Hamiltonian), the inversion of the position of \(2^+_2\) and \(4^+_1\) levels is related to a shape modification of the nucleus (prolate-oblate) and to the existence of anharmonic terms for the kinetic energy. The minimum for the \(0^+_2\) level seems to be predicted\(^6\)(\(c\)) for \(^{186}\)Pt, and also the general trend of the low energy (positive parity) levels.

In the Greiner model\(^7\) (another approach to the Bohr-Mottelson Hamiltonian calculation) one can also find bands interacting strongly with each other, but here the crossing \(2^+_2-4^+_1\) is less significant with respect to a shape modification (prolate-oblate), and the \(0^+_2\) state is a three-phonon state.

In the model described by Holzwart\(^8\), the minimum of the \(0^+_2\) state appears and is related to the anharmonic terms of the Hamiltonian expressed in boson terms (generator coordinate method).

The experimental situation as found in Pt nuclei is also found in Os nuclei\(^6,13\) and we think there exist similar trends in Te, Pd, Gd, Sm, and Ba nuclei\(^27\).
REFERENCES


8) G. Holzwardt (to be published).


27) French-CERN Isolde Collaboration (to be published).
Table 1

Half-life of the first $2^+$ in Os$^{182,184}$ and Pt$^{184,186,188,190}$

<table>
<thead>
<tr>
<th>Energy level (in keV)</th>
<th>Half-life B(E2 $2_1^+ \rightarrow 0_1^+$) exp. in c²cm⁴ $10^{-4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Os$^{182}$ 119.8</td>
<td>$0.95 \pm 0.10 \times 10^{-9}$ sec</td>
</tr>
<tr>
<td>Os$^{184}$ 127</td>
<td>$1.1 \pm 0.05 \times 10^{-9}$ sec</td>
</tr>
<tr>
<td>Pt$^{184}$ 162.4</td>
<td>$360 \pm 12 \times 10^{-12}$ sec</td>
</tr>
<tr>
<td>Pt$^{186}$ 191.5</td>
<td>$260 \pm 10 \times 10^{-12}$ sec</td>
</tr>
<tr>
<td>Pt$^{188}$ 265.4</td>
<td>$72 \pm 13 \times 10^{-12}$ sec</td>
</tr>
<tr>
<td>Pt$^{190}$ 296</td>
<td>$45 \pm 15 \times 10^{-12}$ sec</td>
</tr>
<tr>
<td></td>
<td>$0.666 \pm 0.070$ (* )</td>
</tr>
<tr>
<td></td>
<td>$0.671 \pm 0.040$ (* )</td>
</tr>
<tr>
<td></td>
<td>$0.765 \pm 0.038$</td>
</tr>
<tr>
<td></td>
<td>$0.590 \pm 0.025$</td>
</tr>
<tr>
<td></td>
<td>$0.516 \pm 0.103$</td>
</tr>
<tr>
<td></td>
<td>$0.502 \pm 0.150$</td>
</tr>
</tbody>
</table>

Table 2

Pt nuclei experimental levels energy values (in keV)

<table>
<thead>
<tr>
<th>Level</th>
<th>$^{182}$Pt</th>
<th>$^{184}$Pt</th>
<th>$^{186}$Pt</th>
<th>$^{188}$Pt</th>
<th>$^{189}$Pt</th>
<th>$^{190}$Pt</th>
<th>$^{192}$Pt</th>
<th>$^{194}$Pt</th>
<th>$^{196}$Pt</th>
</tr>
</thead>
<tbody>
<tr>
<td>2$^+$</td>
<td>154.9</td>
<td>162.4</td>
<td>191.5</td>
<td>265.4</td>
<td>296</td>
<td>316.5</td>
<td>328.5</td>
<td>355.7</td>
<td></td>
</tr>
<tr>
<td>4$^+$</td>
<td>418.7</td>
<td>434.6</td>
<td>490.1</td>
<td>670.6</td>
<td>737.5</td>
<td>784.5</td>
<td>811.2</td>
<td>877.3</td>
<td></td>
</tr>
<tr>
<td>6$^+$</td>
<td>771</td>
<td>797.1</td>
<td>877.2</td>
<td>1185</td>
<td>1290</td>
<td>1390</td>
<td>1412</td>
<td>1510</td>
<td></td>
</tr>
<tr>
<td>2$^-$</td>
<td></td>
<td>648.3</td>
<td>607.3</td>
<td>605.9</td>
<td>597.8</td>
<td>612.4</td>
<td>622.1</td>
<td>683.7</td>
<td></td>
</tr>
<tr>
<td>3$^+$</td>
<td></td>
<td>939.6</td>
<td>956.9</td>
<td>936.1</td>
<td>917.2</td>
<td>920.9</td>
<td>922.8</td>
<td>1015</td>
<td></td>
</tr>
<tr>
<td>0$^+$</td>
<td></td>
<td>(492.7)</td>
<td>(471.6)</td>
<td>798.2</td>
<td>921.6</td>
<td>1195.0</td>
<td>1267</td>
<td>1135</td>
<td></td>
</tr>
<tr>
<td>2$^+$</td>
<td></td>
<td>844.3</td>
<td>798.4</td>
<td>1115</td>
<td>1203.4</td>
<td>1576.6</td>
<td>1623</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4$^-$</td>
<td></td>
<td>1236.8</td>
<td>1222.4</td>
<td>(1625)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3$^+$</td>
<td></td>
<td></td>
<td></td>
<td>1407.8</td>
<td>1349.6</td>
<td>1353.7</td>
<td>1378</td>
<td>1432</td>
<td>1447</td>
</tr>
<tr>
<td>1$^-$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1775.3</td>
<td>1737.3</td>
<td>1739.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td></td>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td>(d)</td>
<td></td>
</tr>
</tbody>
</table>

a) This work.


# Table 3

B(E2) branching ratio

<table>
<thead>
<tr>
<th>Levels [i,f]</th>
<th>Pt(^{184})</th>
<th>Pt(^{186})</th>
<th>Pt(^{188})</th>
<th>Pt(^{190})</th>
<th>Pt(^{192})</th>
<th>Pt(^{194})</th>
<th>Pt(^{196})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2^+_1 \to 0^+_1)</td>
<td>11 ± 3</td>
<td>3.3 ± 0.2</td>
<td>1.24 ± 0.05</td>
<td>0.52 ± 0.02 (0.18)</td>
<td>0.21 ± 0.05 (0.22)</td>
<td>7 ± 2 (10^{-6}) (1.44)</td>
<td></td>
</tr>
<tr>
<td>(2^+_1 \to 2^+_1)</td>
<td>100 ± 20</td>
<td>100 ± 5</td>
<td>100 ± 3</td>
<td>100 ± 2 (100)</td>
<td>100 ± 3 (100)</td>
<td>100 ± 3 (100)</td>
<td></td>
</tr>
<tr>
<td>(3^+_1 \to 2^+_1)</td>
<td>15 ± 2</td>
<td>4.5 ± 0.2</td>
<td>2.0 ± 0.2</td>
<td>1. ± 0.10 (0.36)</td>
<td>0.5</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>(3^+_1 \to 2^+_2)</td>
<td>100 ± 30</td>
<td>100 ± 5</td>
<td>100 ± 3</td>
<td>100 ± 2 (100)</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>(2^+_3 \to 0^+_1)</td>
<td>5.5 ± 2</td>
<td>7.9 ± 0.8</td>
<td>0.8 ± 0.1</td>
<td>~ 0.03</td>
<td>~ 1.7 (0.07)</td>
<td>~ 1.7 (0.07)</td>
<td>~ 1.7 (0.07)</td>
</tr>
<tr>
<td>(2^+_3 \to 0^+_2)</td>
<td>100 ± 30</td>
<td>100 ± 10</td>
<td>100 ± 10</td>
<td>100 ± 10 (100)</td>
<td>100 ± 10 (100)</td>
<td>100 ± 10 (100)</td>
<td></td>
</tr>
<tr>
<td>(2^+_3 \to 2^+_1)</td>
<td>≤ 6</td>
<td>0.6 ± 0.1</td>
<td>0.6 ± 0.1</td>
<td>0.3 ± 0.1 (0.11)</td>
<td>0.3 ± 0.1 (0.11)</td>
<td>0.3 ± 0.1 (0.11)</td>
<td></td>
</tr>
<tr>
<td>(2^+_3 \to 2^+_2)</td>
<td>≤ 6</td>
<td>0.6 ± 0.1</td>
<td>0.6 ± 0.1</td>
<td>0.3 ± 0.1 (0.11)</td>
<td>0.3 ± 0.1 (0.11)</td>
<td>0.3 ± 0.1 (0.11)</td>
<td></td>
</tr>
<tr>
<td>(4^+_2 \to 2^+_2)</td>
<td>8 ± 1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(4^+_2 \to 2^+_1)</td>
<td>2.1 ± 0.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(4^+_2 \to 2^+_3)</td>
<td>-</td>
<td>100 ± 10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(0^+_2 \to 2^+_1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11 ± 1</td>
<td>3.9 ± 0.4 (15)</td>
<td>7.9 ± 0.8</td>
<td>14 ± 2</td>
</tr>
<tr>
<td>(0^+_2 \to 2^+_1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100 ± 10</td>
<td>100 ± 5 (100)</td>
<td>100 ± 5 (100)</td>
<td>100 ± 10 (100)</td>
</tr>
</tbody>
</table>

(a) This work.


$B(E2 \ 2^+_1 \rightarrow 0^+_1)$ for PT NUCLEI

- exp. points (this work)
- other exp. points
- KUMAR values

Fig. 1: $B(E2 \ 2^+_1 \rightarrow 0^+_1)$ exp. values for Pr$^{184,186,188,190}$. 
Fig. 2: $B(E2 2^+_1 \rightarrow 0^+_1)$ exp. values for Os$^{182,184}$. 

$B(E2 2^+_1 \rightarrow 0^+_1)$ for OS NUCLEI

- exp. points (this work)
- other exp. points
- KUMAR values
Fig. 3: Energy levels for Pt$^{182-196}$ nuclei.
Fig. 4: $\frac{B(E2; 2^+_0 \rightarrow 0^+_1)}{B(E2; 2^+_1 \rightarrow 2^+_1)}$ exp. values for Pt nuclei.