[ORGANI]ZATION FOR NUCLEAR RESEARCH

STAGGERING OF THE MOMENTS OF INERTIA OF VERY NEUTRON-DEFICIENT PLATINUM ISOTOPES

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ABSTRACT

Rotational states in the lightest isotopes of platinum (Z = 78) have been located through the fine structure in alpha decay. For ^{176}Pt the first 2^+ level is at 263 keV. The favoured alpha transitions in the decay of the odd isotopes $^{181-185}$Hg unambiguously identify the bandhead of the $\frac{1}{2}^-$[521] Nilsson states in the platinum daughters. In the region N = 98-104 the moments of inertia show a dramatic even-odd staggering amounting to a factor of 2; this behaviour parallels the staggering in $\langle r^2 \rangle$ in the mercury (Z = 80) isotopes.

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Recent measurements [1] by laser spectroscopy of the isotope shifts in the optical $^3P_1 \rightarrow {}^1S_0$ transition in light isotopes of mercury (Z = 80) have confirmed and extended a picture that had already emerged from the combination of optical data for the light odd-mass nuclei [2] with gamma-spectroscopic evidence [3] for the even nuclei. While the odd mass mercury nuclei lighter than ^{187}Hg are strongly deformed, the even mass nuclei ^{184,186}Hg retain near-spherical shapes as shown by their small radii [1] and high-lying first-excited 2^+ states [3]. A discussion of how theory has accommodated itself to these results can be found in refs. [1] and [2]; suffice it to say here that the main effect seems to arise from the presence of two minima in the nuclear potential-energy surface, one slightly oblate, one strongly prolate [4]. The even-odd effect has been ascribed to pairing which makes the latter minimum occur lowest in energy in odd-mass nuclei [5] with $A \leq 185$.

In the present work we exploit the alpha-decay fine structure to study selectively the moments of inertia for low-lying rotational bands in neutron-deficient isotopes of platinum (Z = 78). The experiments were carried out by techniques similar to those used in our previous alpha-decay studies [6,7] but now benefitting from the high beam intensities available at the ISOLDE-2 facility at CERN and from improved data-taking techniques for the alpha-gamma coincidence measurements. In a subsequent paper [8] the experimental techniques and results will be presented in more detail, and new information on alpha widths and Q-values will be discussed. The focus of the present letter is on the rotational fine structure, which gives striking evidence for a pronounced even-odd staggering of the moments of inertia of light platinum nuclei. The relevant experimental information is given in table 1 and in fig. 1, which are based on refs. [6-14] and the present work.

The measured spins, magnetic moments, and isotope shifts [2] of the odd-mass isotopes $^{181-185}$Hg characterize their ground states as the $\frac{1}{2}^-[521]$ Nilsson orbital in all three cases. Their favoured alpha transitions (table 1) therefore unambiguously identify the same state in the platinum daughters ^{177,179,181}Pt.

In all three cases the alpha decay populates two states at approximately 70 and 90 keV above the band head with reduced widths of 5-15% relative to the transition to the band head. The systematic occurrence of these transitions can only be understood when interpreted as the d-wave alpha decay to the $3/2^-$ and $5/2^-$ rotational states. (A fourth state identified in ^{179}Pt is consistent with the $7/2^-$ state.)

If it is assumed that the spin sequence in the band is $1/2$, $3/2$, $5/2$ as in the Yb isotopes [13], the moment-of-inertia parameter $\hbar^2/2\mathscr{J}$ and the decoupling parameter $\underline{a}$ can be calculated from the results given in table 1 by application of the expression for the rotational energies

$$E_I = E_0 + \hbar^2/2\mathscr{J} \left\{ I(I+1) + \underline{a}\, \delta_{K,\frac{1}{2}} (-1)^{I+\frac{1}{2}} (I + \tfrac{1}{2}) \right\} .$$

The values 0.63 to 0.80 obtained for $\underline{a}$ agree well with the values 0.8-0.9 calculated from the Nilsson model [15], according to which the decoupling parameter for this orbital is almost independent of deformation. In the case (unlikely but not excluded by our experiments) that the spins of the two excited band members were to be reversed, the parameter $\underline{a}$ would take values 1.2-1.4; the moments of inertia at the same time would decrease by only 3-7%, so that the conclusions of the present work would remain unchanged.

As previously pointed out [6], the energies of the rotational 2^+ states display a minimum of 150 keV near the mid-point of the 82-126 neutron shell (N = 104). The observation in the present work of an excited 2^+ level at 263 keV in ^{176}Pt provides evidence that the lower limit of the deformed even platinum isotopes has been reached. It is interesting to note that the new state is almost identical in energy with the 265.6 keV 2^+ state [10,11] in ^{188}Pt, with which ^{176}Pt lies symmetrically with respect to N = 104. The systematics of the 2^+ energies in even platinum isotopes is given in fig. 1, which shows the moment-of-inertia parameter defined as $E_{2^+}/6$ as a function of A. The 2^+ energies agree well with theoretical predictions from a Strutinsky-type calculation [16,17].

It is instructive to compare the inertial parameters of the odd and even isotopes of platinum with those of ytterbium (fig. 1). In this connection it should be remembered that the effective moment of inertia of an odd-mass nucleus is increased above the core value through a reduction in the pair correlation due to the odd particle and through the Coriolis coupling between the one-quasi-particle states [18]. The Coriolis effect is especially strong for Nilsson states originating in high-j orbitals. The deformed rotational bands occurring in the "spherical" regions of the nuclear chart (see, for example, the discussion by Kleinheinz et al. [19]) are usually of this type and have strong Coriolis contributions.

For the $1/2^-$[521] band in the ytterbium isotopes, the non-diagonal contribution from the Coriolis interaction is weak, of the order of only 10% [20], and it seems unlikely that it can account for the even-odd staggering of a factor of 2 or more observed in the platinum case (fig. 1). Therefore it appears likely that a major contribution comes from a difference in shape between the even and the odd platinum isotopes. The behaviour of the moments of inertia in the lightest platinum isotopes is thus parallel to the staggering of the radii in the light mercury isotopes [1,2], and most likely it is another manifestation of one and the same effect occurring near the neutron number N = 104.

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Table 1

Excited levels in neutron-deficient platinum isotopes populated in alpha decay of mercury

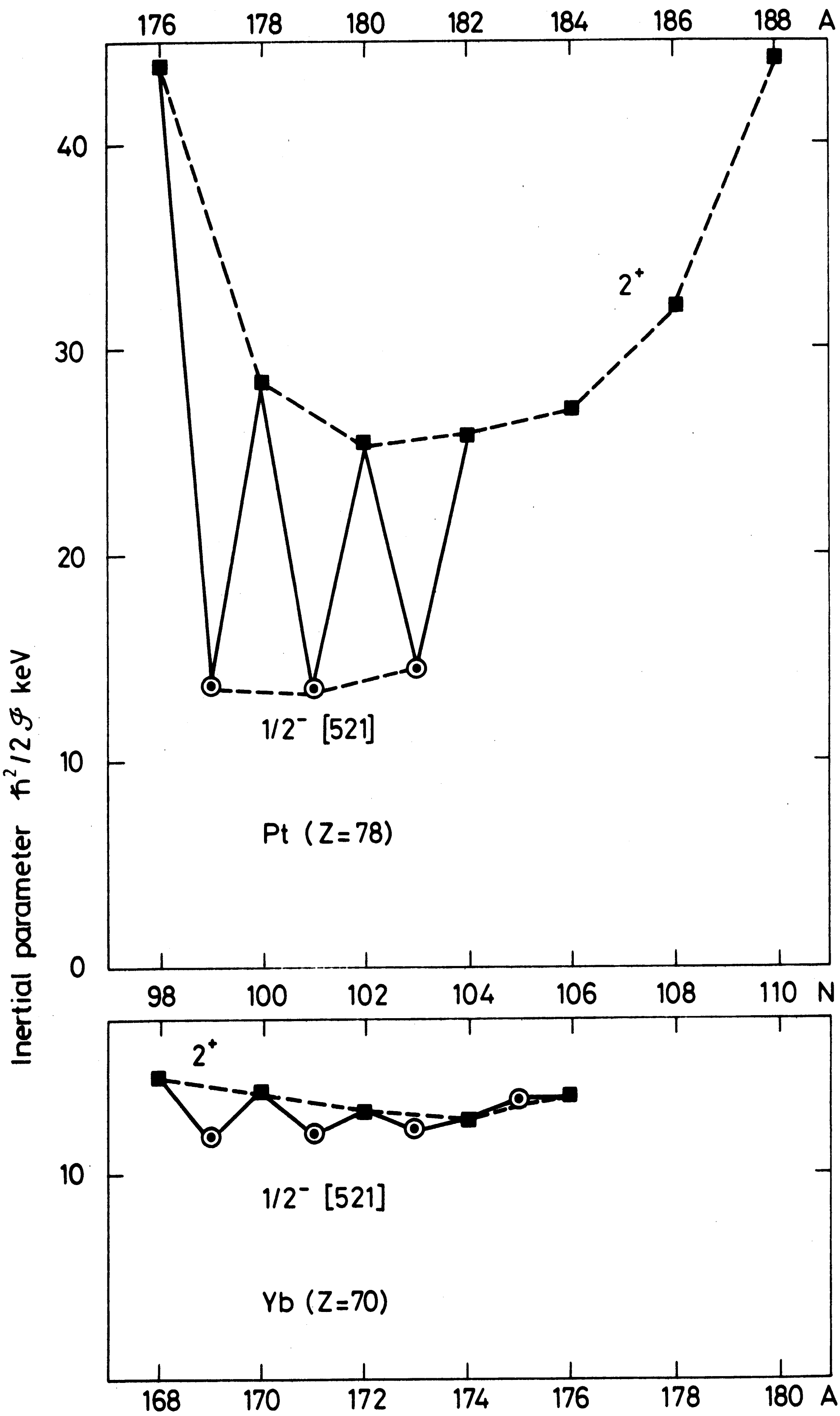
I^π	Level (keV), α-intensity (%) and reduced width a)				$\hbar^2/2\mathcal{J}$	a
	$1/2^-$	$(3/2^-)$	$(5/2^-)$	$(7/2^-)$		
177	147.2 (23) (1.04)	214.2 (1.6) (0.14)	239.8 (1.2) (0.13)		13.7	0.63
179	0 (10.6) (0.49)	71.4 (0.61) (0.057)	87.4 (0.43) (0.047)	241.2 (0.03) (0.016)	13.5	0.76
181 b)	0 (4.6) (0.49)	79 (0.12) (0.029)	94 (0.08) (0.023)		14.7	0.80
I^π	0^+	2^+				
176	0 (30) (0.59)	263 (0.016) (0.004)			43.8	
178	0 (9) (0.50)	170.7 (0.052) (0.016)			28.5	

a) Defined by removing the s-wave barrier penetration (J.O. Rasmussen, Phys. Rev. 113 (1959) 1593 and in units such that $W(^{212}P_0) \equiv 1$. (See also ref. [7].)

b) The scheme given here represents a re-interpretation [8] of the data given in ref. [13].

Figure caption

Fig. 1 : Moment-of-inertia parameters $\hbar^2/2\mathcal{J}$ as a function of mass number for isotopes of platinum (Z = 78) and, for comparison, of ytterbium (Z = 70) [12,13]. For the even isotopes the value given is $E_{2^+}/6$, where E_{2^+} has been taken from following references. Mass 176, 178, 263 keV, 170.7 keV (present work), mass 180, 152 keV [6,8], masses 182-188, 155, 163, 192, 266 keV [10,11]. For the odd-mass platinum isotopes the data were taken from table 1.



176
178
180
182
184
186
188
A
40
30
20
10
0
2+
1/2⁻ [521]
Pt (Z=78)
Inertial parameter ħ²/2ℐ keV
98
100
102
104
106
108
110
N
2+
10
1/2⁻ [521]
Yb (Z=70)
168
170
172
174
176
178
180
A

Fig. 1