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LEVELS IN ^{192}Os EXCITED BY THE (p, p′) AND (d, d′) REACTIONS (*)

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Résumé. — Les niveaux d'énergie de ^{192}Os ont été étudiés par réactions (p, p′) et (d, d′). Les spectres γ et les coïncidences γ-γ ont été enregistrés à des énergies de protons de 16 MeV et de deutons de 23,2 MeV. En dehors des niveaux déjà connus, des états de parité négative ont été observés. La possibilité d'une forme triaxiale pour ce noyau est envisagée.

Abstract. — The energy levels of ^{192}Os were studied by the (p, p′) and (d, d′) reactions. Single gamma ray spectra and γ-γ coincidences were measured at 16 MeV (protons) and 23.2 MeV (deuterons) incident energy. Negative parity states were observed in addition to previously known levels. The possiblity of the triaxial shape for this nucleus is discussed.

1. **Introduction.** — Levels of the heaviest stable osmium isotope ^{192}Os are known from the decay of 5.9 s isomeric state in this nucleus, excited by the (n, n′) reaction [1], from Coulomb excitation experiments [2, 3] and from ^{192}Re [1] and ^{192}Ir [4] decays.

This paper reports the results obtained during in-beam studies of ^{191}Ir by (p, 2n) and (d, 3n) reactions on a ^{192}Os target [5]. A number of gamma transitions could be attributed to the target excitation.

2. **Experimental procedure and results.** — 2.1 EXPERIMENTAL SET-UP. — The metallic Os target (enriched to 99 % ^{192}Os), approximately 20 mg/cm^2 thick, deposited on 2 mg/cm^2 mylar backing was irradiated with 16 MeV protons and 23.2 MeV deuterons from the Grenoble variable energy cyclotron. Single gamma-ray spectra and γ-γ coincidences were measured with 45 and 77 cm^3 Ge(Li) detectors. Details of the experimental arrangement were published previously [6] and will not be further discussed here.

The list of gamma lines belonging to ^{192}Os is presented in table I. Attribution of the transitions to this nucleus was made on the basis of coincidences with lines placed in the decay scheme of the 5.9 s isomeric state [1].

Some typical coincidence spectra are shown in figure 1.

2.2 LEVEL SCHEME. — The level scheme deduced from the coincidence data is presented in figure 2*a*. This scheme is in good agreement with that proposed in ref. [1]. At most three levels of the rotational bands built on the ground, $KI^\pi = 22^+$ and 44^+ states are fed at the projectile energies used. But we report a 3^-, 1 341 keV state and the first member of its rotational band ($I^\pi = 4^-$, $E = 1\,560.6$ keV). Our attribution of spin and parity to these levels is based on their decay modes and on the negative parity state systematics in the even Os nuclei shown in figure 3.

Figure 2*b* shows the cross-sections for the excitation of some levels in ^{192}Os. Their relative values are based on the intensity balance for each level. The absolute cross-section was estimated by comparison of the intensities of the transitions feeding the ^{191}Ir ground state in the (p, 2n) and (d, 3n) reactions, with the cross-sections predicted for these reactions by the hybrid model [7]. For bombarding energies near the maximum of the excitation function these predictions should be correct within 20 % accuracy.

(*) This work was performed within the Grenoble-Swierk collaboration.

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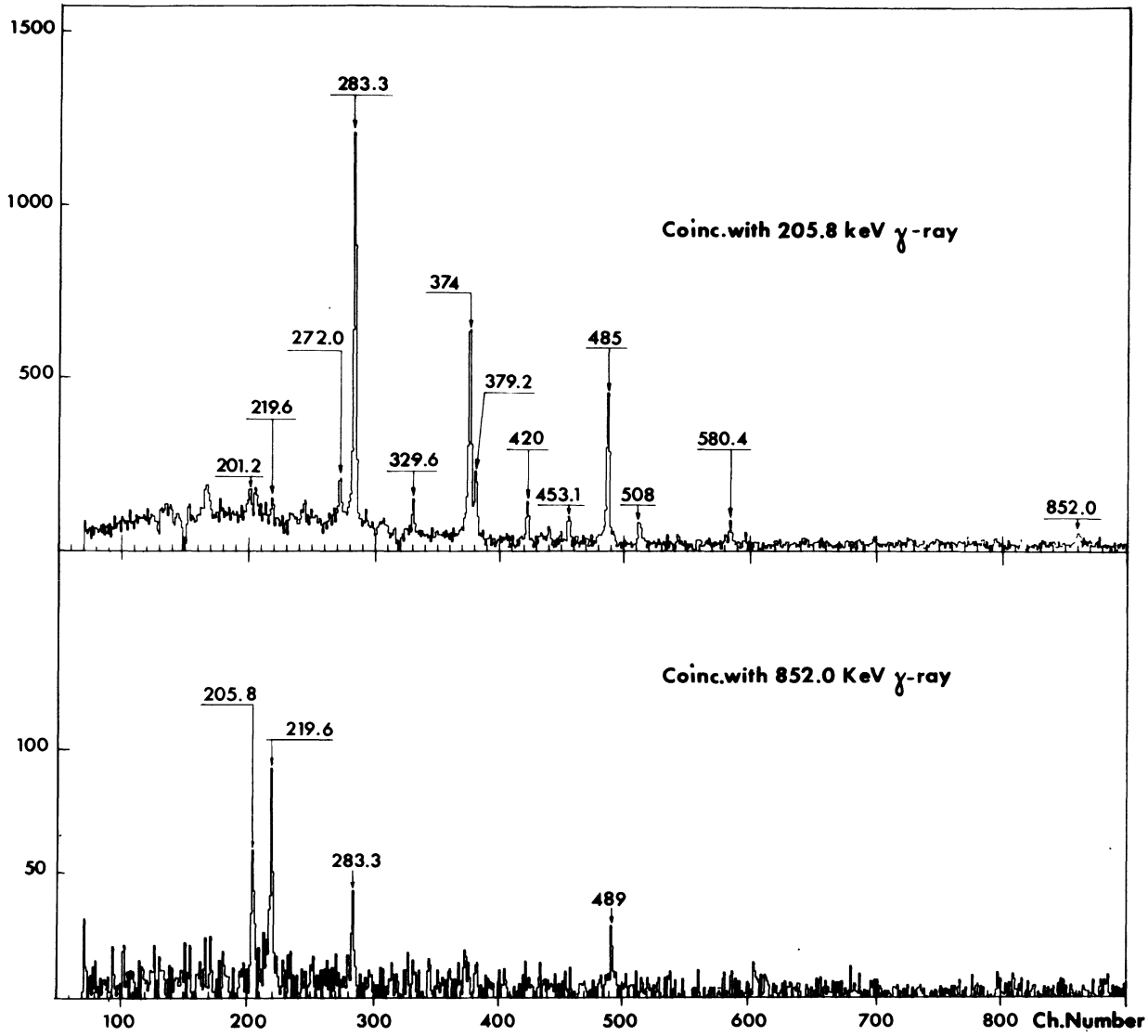

FIG. 1. — Typical coincidence spectra.

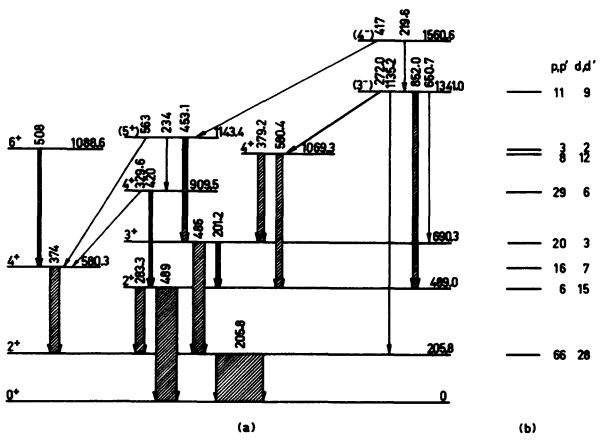

FIG. 2. — *a*) Levels in ^{192}Os excited in (p, p′) and (d, d′) reactions.
b) Absolute cross-sections (in mb) for the excitation of some levels.

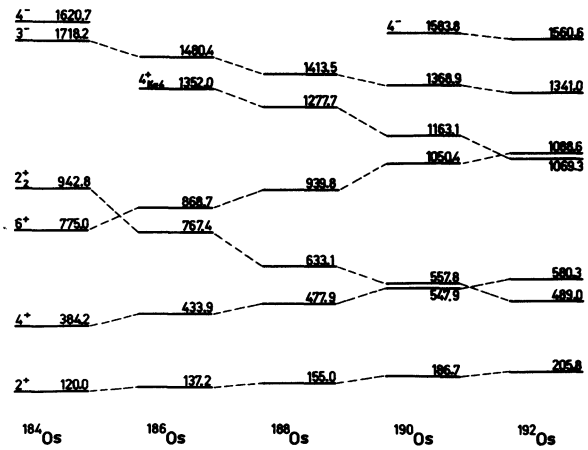

FIG. 3. — Level systematics in even osmium isotopes.

TABLE I

The energies and relative intensities of γ-rays observed in the (p, p′) *and* (d, d′) *reactions on* ^{192}Os *target*

Energy ([a]) (keV)	Relative intensity ([b]) (p, p′)	(d, d′)	Placement (keV)
—	—	—	—
168.4	([c])	26(4)	
201.2	47(4)	48(4)	690.3 → 489.0
205.8	1 000	1 000	205.8 → 0
219.6 ([d])	10(5)	10(5)	1 560.6 → 1 341.0
234 ([c])	3(1) ([f])	4(1) ([f])	1 143.4 → 909.5
242.4	70(10)	129(9)	
272.0	34(6)	53(4)	1 341.0 → 1 069.3
283.3	176(7)	224(16)	489.0 → 205.8
329.6	67(10)	29(3)	909.5 → 580.3
348.5		26(4)	
374 ([d])	220(80) ([e])	220(80) ([e])	580.3 → 205.8
379.2	37(9)	156(17)	1 069.3 → 690.3
417 ([c,d])			1 560.6 → 1 143.4
420 ([d])	220(20) ([f])	100(15) ([f])	909.5 → 489.0
437	16(5)	16(5)	
453.1	86(12)	107(12)	1 143.4 → 690.3
485 ([d])	270(30) ([f])	270(30) ([f])	690.3 → 205.8
489 ([d])	235(30) ([f])	430(40) ([f])	489.0 → 0
508 ([d])	30(10) ([e])	45(15) ([e])	1 088.6 → 580.3
563 ([c])	18(2) ([f])	22(2) ([f])	
580.4	88(12)	142(15)	1 069.3 → 489.0
591 ([c])			
650.7	weak	24(4)	1 341.0 → 690.3
852.0	72(10)	91(11)	1 341.0 → 489.0
1 135.2	([g])	24(4)	1 341.0 → 205.8

([a]) Energy error is 0.1 keV for strong and well resolved lines and can attain 0.8 keV for weak or badly resolved transitions.

([b]) Values are given for 16 MeV and 23.2 MeV incident energy of protons and deuterons, respectively. Uncertainties in the least significant figures are given in parentheses.

([c]) Line observed in coincidence spectra only.

([d]) Complex line.

([e]) Estimated from the coincidence spectra.

([f]) Calculated from the branching ratio of transitions deexciting the given level [1].

([g]) Out of energy range.

3. **Discussion.** — The 3^- and 4^- states in ^{192}Os at 1 341 keV and 1 560.6 keV respectively were not found in the decay studies [1, 3, 4]. It seems likely that the former is identical to the 3^-, 1 333 keV state observed in the inelastic scattering of α particles and reported by Baker *et al.* [3] during the preparation of our note.

Comparison of the branching ratios for the decay of 3^- state with the predictions of the Alaga rule is presented in table II. The best agreement is found

TABLE II

E1 *transitions from the* 3^- *state to the* $K = 2$ *band in* ^{192}Os

Transition	Exp.	B(E1) (relative) Alaga rule $K_i = 1$	$K_i = 2$	$K_i = 3$
—	—	—	—	—
$3^-, K_i \to 2^+, K_f = 2$	1.0	1.0	1.0	1.0
$3^-, K_i \to 3^+, K_f = 2$	0.59 ± 0.12	8.87	1.40	0.35
$3^-, K_i \to 4^+, K_f = 2$	< 0.3	11.4	1.80	0.05

for the assumption of $K = 3$ for the level considered. This supports the interpretation of the 3^- state as the octupole one, as in the lighter osmium isotopes [8]. However, the 3^- state in ^{192}Os decays also to the $KI^\pi = 02^+$ (205.8 keV) level with a branching ratio : B(E1, 1 135.2 keV)/B(E1, 852.0 keV) = 0.11. So in this case K is not a good quantum number. This fact may be due to the triaxiality of the ^{192}Os nucleus. Such assumption can also explain the inversed order of $KI^\pi = 22^+$ and 04^+ levels (cf. Fig. 3) in this isotope.

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