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THE LIFETIME AND NATURE OF THE 686-*kev* *LEVEL IN* Re^{187}

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The half-life of the 686-kev level in Re^{187} was measured by the delayed coincidence method and found to be $T_{1/2} = (2 \pm 0.7) \times 10^{-10}$ sec. The E1 and E2 transition probabilities are compared with the corresponding ones calculated by the Nilsson model. The 686-kev level is not necessarily a vibrational level.

THE level scheme of Re^{187} has been studied by many authors.[1,2] Nonetheless the nature of the 686 and 511 kev levels is not clearly understood. Gallagher, Edwards, and Manning,[1] who compared the distribution of these levels with computations based on the Nilsson model conclude that both levels are vibrational. If so, these are the first vibrational levels to be discovered in odd nuclei.

Since the energy predictions of the Nilsson model are rather approximate, we shall consider in this paper the transition probabilities of the 686- and 511-kev levels of the Re^{187} nucleus and the 646-kev level of the Re^{185} nucleus.

The ground state of Re^{185} and Re^{187} has a spin $^5/_2$ and, according to Mottelson and Nilsson,[3] corresponds to the Nilsson state [402], No. 27. By analogy with the 646-kev level in the Re^{185} nucleus[3,4], one can assume that the 511-kev level with spin $^1/_2$ is the state [400]. It is easy to see that E2 transitions from both the 511 and 686 kev levels are permitted by the asymptotic selection rules.[3] Nilsson's wave functions[3] were used to compute the E2 transition probabilities B(E2). These were found to agree with those given by the Weisskopf formula. The measured B(E2) values for these two transitions obtained by the Coulomb excitation method were 4 to 6 times larger than the theoretical ones.[4]

As for the 686-kev level with spin $^5/_2$, it corresponds to Nilsson's state [532 $^5/_2$], No. 36. Under these conditions a 480 kev E2 transition is hindered.[3] Computation of the probability $P_{\gamma E2}$ of this transition by the Nilsson method yields a degree of hindrance 10 times what it is according to the Weisskopf formula. Such hindered E2 transitions have been found in deformed Ta^{181} and Np^{237} nuclei.[3]

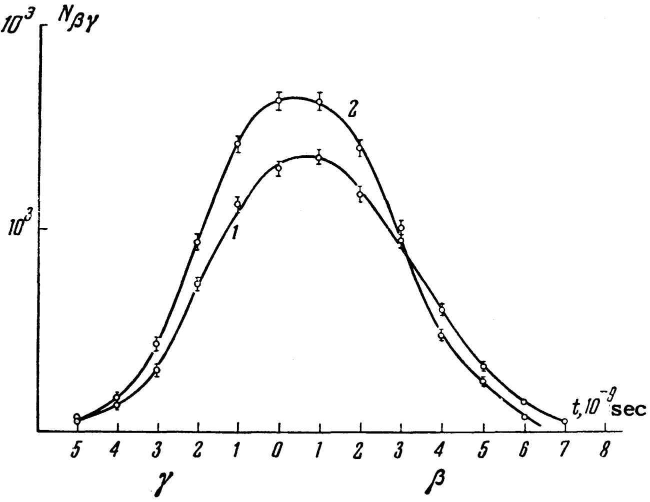
In the case of these nuclei the experimental values for the degree of hindrance (according to the Weisskopf formula) vary within a range of 20 to 400. Taking $P_{\gamma E2} = 2.5 \times 10^8$ sec^{-1}, we obtain for the half-life of the 686-kev level the value $T_{1/2} = 1.2 \times 10^{-9}$ sec (where we have also taken into consideration the data in[1,2] for the γ-ray intensity ratios).

This period was measured experimentally by the method of delayed $\beta - \gamma_{480}$ and $\beta - \gamma_{686}$ coincidences. The β-particles were detected with an anthracene counter and the photons with a NaI(Tl) crystal. The resolving time of the "fast-slow coincidence" circuit[5] was 6×10^{-9} sec. The delayed coincidence curves were compared with instantaneous resolution curves for Co^{60}. In both cases the centers of gravity of the curves were shifted by an amount $\Delta = (3 \pm 1) \times 10^{-10}$ sec. Hence, the half-life of the 686-kev level is $T_{1/2} = (2 \pm 0.7) \times 10^{-10}$ sec, and the ratio of the experimental and theoretical (Nilsson's) probabilities $P_{\gamma E2}$ is 6.

Thus, our result indicates a larger value for the probability of the E2(480 kev) transition than does the Nilsson model. Results of a similar nature were also obtained for E2 transitions with energies of 646 and 511 kev in Re^{185} and Re^{187} nuclei respectively.

At this point it should be noted that for hindered E2 transitions in Ta^{181} and Np^{237} nuclei where Nilsson's description is assumed to be accurate, the experimental values for B(E2) also exceed Nilsson's theoretical values.[6] Therefore, the divergence observed in the case of Re^{187} for the hindered E2(480 kev) transition is no particular reason to assume that the 686-kev level is not a Nilsson state. The excess of the transition probabilities over those predicted by the Nilsson and Weisskopf formulae in the cases of Re^{185} and Re^{187} nuclei can be explained by the fact that for these nuclei the strong coupling approximation is not quite accurate.

Nucleus	Transition energy in kev	Ratio of the E2 transition probability to probability computed by the Weisskopf formula	Nucleus	Transition energy in kev	Ratio of the E2 transition probability to probability computed by the Weisskopf formula
$_{75}Re^{185}$	646	4.5 (permitted)	$_{79}Au^{197}$	78	28
Re^{187}	480	0.7 (hindered)		279	27
	511	6 (permitted)		550	25
$_{77}Ir^{191}$	82.6	15	$_{81}Tl^{203}$	279	10
	356	47		689	7
Ir^{193}	73	25	Tl^{205}	205	5
	368	20	$_{82}Pb^{207}$	569	1,5



Delayed coincidence curves: 1) W^{187} nucleus, $\beta-\gamma_{480}$ coincidence, 2) Co^{60} nucleus, $\beta-\gamma_{480}$ coincidence (Compton electrons from 1.17- and 1.33-Mev γ quanta). (The numbers on the abscissa to the left of zero correspond to the delay of the pulse from the γ counter, and to the right of zero to the β-counter delay.)

These slightly deformed nuclei may represent an analogy with the transition zone nuclei[7] listed in the table. The examined levels are single-particle levels with collective effects that increase the probability of E2 transitions.

Assuming that the 686 kev level is the [532 $^5/_2$] state in Nilsson's nomenclature, we can compute the E1 transition probabilities for the 686 and 552 kev radiations. The transition probabilities given here for these two γ-radiations are in good agreement with the values computed by the Alaga formula. It must be said of this type of transition and generally of E1 transitions in deformed nuclei[8] that their experimental probabilities are either equal to the theoretical values based on the Nilsson model or about ten times smaller. Indeed, according to Nilsson $P_{\gamma E1}(686) = 2.3 \times 10^{10}\ \text{sec}^{-1}$, which is about 10 times the experimental value for $P_{\gamma E_1}$.

Moreover, the relatively low energy of these levels tends to indicate that they are not of a vibrational nature. Nathan and Popov[4] think that they observed vibrational levels in odd Tb^{159} and Ho^{165} nuclei whose transition probabilities were of the same order as those computed by the Weisskopf formula. It is worth noting that these levels have lower energies than the vibration energies computed on the basis of the vibration rotation interactions observed in the indicated nuclei.[9]

Thus, we cannot assert (unlike Gallagher, Edwards, and Manning[1]) that the 686- and 511-kev levels in the Re^{187} nucleus are vibrational. Our result tends rather to indicate that the 686-kev level is a single-particle state. To reach a more definite conclusion we would need to know the theoretical values based on the intermediate coupling hypothesis, both for transitions from vibrational levels in odd nuclei (to determine whether they are close to the values obtained by the Weisskopf formula) and for the 480 kev transition of the Re^{187} nucleus.

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