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CORIOLIS INTERACTIONS IN ODD-ODD NUCLEI: Am^{242m} ALPHA DECAY

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ABSTRACT

Nuclear spectroscopic studies of the alpha decay of Am^{242m} have led to the identification of new excited states and gamma ray transitions in Np^{238}. All of the observed levels compare favorably with the predictions from odd-mass nuclei. This is especially true for the observed moments of inertia.

A number of the gamma ray intensities were interpreted in terms of Coriolis interactions between states having common neutron and proton quasi-particles and differing in K by 1. Most of the other gamma ray intensities could be related to transitions in odd-mass nuclides. For some transitions it was necessary to postulate explanations involving multiple-order Coriolis effects and residual neutron-proton interactions.

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In an earlier report on the alpha decay scheme of Am^{242m}, it was shown that the low-lying energy levels of Np^{238} and some of the transition probabilities could be described in terms of proton and neutron quasi-particle states. In the present study additional measurements on Am^{242m} alpha decay have led to a better understanding of some of the interactions present in odd-odd nuclei. The Np^{238} energy level scheme and quasi-particle assignments are shown in Fig. 1. Also shown are calculated energies of the intrinsic levels in Np^{238}. These are simply sums of the odd-neutron and odd-proton values with a splitting of 50 keV for $\Omega(p) \pm \Omega(n)$, a value found experimentally in Am^{242}. It is seen that the the predicted levels occur in the right order and the calculated energies are accurate to ~70 keV. The moments of inertia were also calculated for the various rotational bands by subtraction of the appropriate even-even value from the sum of the odd-proton and odd-neutron values. As shown in the figure the agreement with the observed values is excellent.

The reduced transition probabilities for those transitions in Np^{238} in which only one quasi particle changes its nuclear quantum numbers are all roughly consistent with the odd-mass values and will not be discussed further here. Other types of transitions involving changes in both quasi-particle states should be prohibited for pure states. It is seen in the figure that this latter type of decay occurs to a marked degree in the de-excitation of the 3-3 ($K\Pi$) level to the 2+ ($K\Pi$) band. The relative intensities of these gamma rays, however, vary by over an order of magnitude from the expectations for parent and daughter states with pure K. Thus these states must contain appreciable admixtures of K values other than the indicated principal assignments. The two K values for bands AZ, 2+ and 3+, differ by only one unit of angular momentum, and hence would be expected to interact via the Coriolis force. For these bands, which have a common $\Omega = 1/2$ neutron state, the matrix element of the interaction is equal to the decoupling parameter. This would also be true for the 2- and 3- bands of BZ. We were thus able to calculate the relative intensities of the various gamma rays de-exciting the 3-3 state with respect to the 49.4 keV E1 gamma ray. We have assumed a Coriolis matrix element of -0.4, which is the average of the Pu^{239} and U^{235} decoupling parameters for neutron state Z. In addition we assumed that levels at 215 and 259 keV, which were indicated by somewhat dubious alpha groups, are indeed the 2-3 and 2-4 states. The resulting theoretical intensities for the E1 gamma rays to the 2 + 2, 2 + 3, and 2 + 4 states are 1.3, 6.0, and 1.5 per cent respectively, in reasonable agreement with the experimental values 2.1, 5.8, and ~1.3(?) per cent.

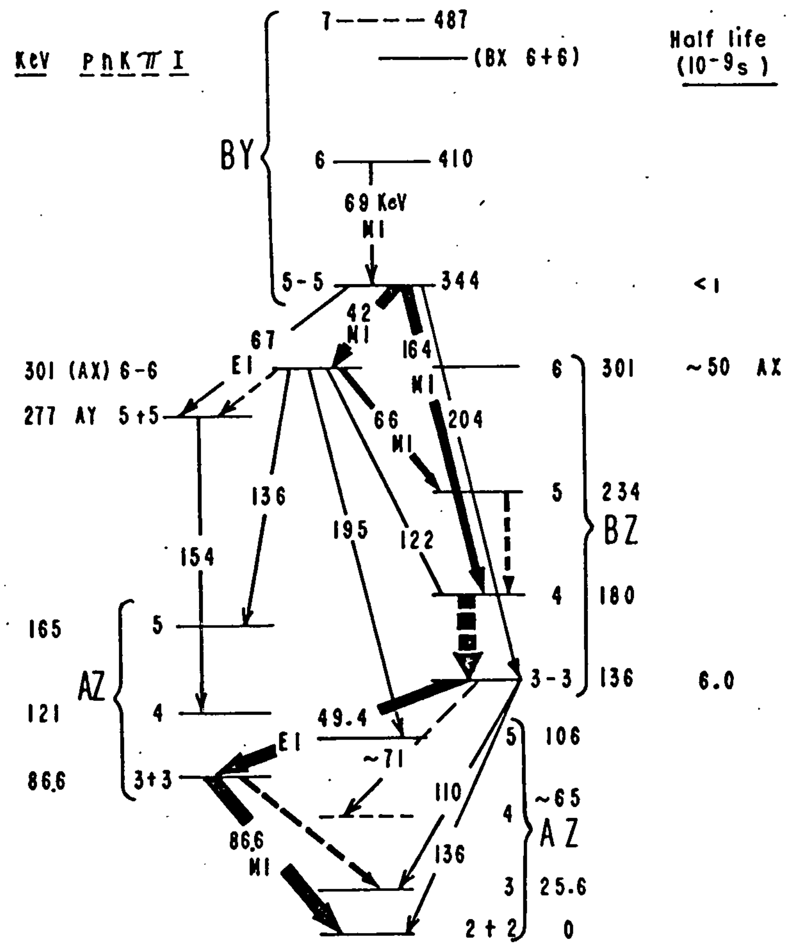
This Coriolis mechanism can be further investigated by considering the transitions de-exciting the 6-6 state. The 122 keV E2 transition between the 6-6 and 3-4 levels has a retardation factor of only 6 over the single particle value, although such a K-forbidden transition would be expected to be retarded by about a factor of 100. This effect may be explained by an interaction between the very close-lying 6-6 and 3-6 levels which would cause the 122 keV E2 to be collectively enhanced. With this assumption we calculated intensities of the E1 transitions de-exciting the 6-6 state to the 3 + 5 and 2 + 5 states to be 1.1 and 0.3 per cent respectively. The good agreement with the observed values, ~2 and ~0.3 per cent, helps confirm the interpretation of a Coriolis interaction between the bands AZ and between bands BZ. The admixture (0.10 per cent when squared) between the 6-6 and 3-6 states is not as nicely understood.

In a similar odd-mass example, two close-lying states in Cf^{251} with $\Delta K = 3$ interacted via a multiple-order Coriolis interaction with an admixture of 0.2 per cent. A similar mechanism (coupled to neutron-proton residual interactions) may be responsible for the Np^{238} admixture.

The transition between BY and AX also involves a change in both quasi-particle states. Small admixtures of the order of ~1 per cent of states CX or AV in state BY would be sufficient to explain the observed minimum transition probability. H. Mang and N. K. Glendenning have calculated a residual neutron-proton interaction matrix element between the states CX and BY to be ~100 keV, which is sufficiently large to give the required admixture.

FIGURE CAPTION

Fig. 1. Energy level scheme of Np^{238}. The dashed quantities and those in parentheses are either uncertain or not directly observed.



Odd-proton Nilsson states

C 3/2 +[6 5 1 ↑]
B 5/2 −[5 2 3 ↓]
A 5/2 +[6 4 2 ↑]

Odd-neutron Nilsson states

V 5/2 − [7 5 2 ↑]
W 7/2 + [6 2 4 ↓]
X 7/2 − [7 4 3 ↑]
Y 5/2 + [6 2 2 ↑]
Z 1/2 + [6 3 1 ↓]

Odd-odd states

PN	Kπ	Energy (KeV) calc.	Energy (KeV) exp.	$\hbar^2/2\mathcal{J}$ (KeV) calc.	$\hbar^2/2\mathcal{J}$ (KeV) exp.
BX	6+	388	464		
	1+	338			
BY	5−	338	344	5.49	5.48
	0−	288			
AX	1−	318			
	6−	268	301		
AY	0+	272			
	5+	222	276		
BZ	2−	117	~180?	5.43	5.5?
	3−	67	136	5.43	5.5
AZ	3+	50	87	4.27	4.3
	2+	0	0	4.27	4.27

Fig. 1

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