STUDY OF $^{159}$Ho, $^{89}$Nb AND $^{107}$Tl IN ($^{3}$He, 3n$^{2}$) REACTIONS

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Abstract

The properties of $^{159}$Ho, $^{89}$Nb and $^{107}$Tl have been studied by means of in-beam $\gamma$-ray spectroscopy. Assignments have been made in $^{159}$Ho for the bands built on the Nilsson states 7/2$^-$[523], 1/2$^+$[411] and 1/2$^+$[541]. Eight new levels have been introduced in the level scheme of $^{89}$Nb, from which four form the succession 13/2$^+$, 17/2$^+$ and 21/2$. In the $^{107}$Tl nucleus, the low-lying 9/2$^+$ state is interpreted as an oblate deformed one and corresponding rotational states are proposed.

1. Measurements

The beam of 28 MeV $^{3}$He$^-$ ions accelerated in U 120 cyclotron has been utilized for the investigation of nuclei produced in the ($^{3}$He, 3n$^{2}$) reaction. Reactions ($^{3}$He, 3n$^{2}$) have the threshold energy of about 10 - 15 MeV and thus it was possible to observe the same final nucleides as those produced in ($\alpha$,4n) reactions at higher energies.

It was possible to decrease the energy of $^{3}$He$^-$ ions gradually in 2 MeV steps from the maximum energy of 28 MeV down to 20 MeV by introducing Al-films into the beam. The beam scattered by the stopping foils was focussed onto the target by means of quadrupole lenses.

The $\gamma$-ray spectra were measured by means of coaxial Ge(Li) detectors with active volumes of 7 - 40 cm$^{-3}$ and the corresponding FWHM 1.2 - 1.5 keV at the 122 keV. The $\gamma$-$\gamma$ coincidences, angular distribution and lifetime characteristics were studied, too. When analysing the results we have observed number of reactions competing with the ($^{3}$He, 3n) reaction studied, as e.g.: ($^{3}$He,4n),(3$^+$He,2n),(3$^+$He,pn), ($^{3}$He, p2n), ($^{3}$He, 2pn) and ($^{3}$He, 2p3n).

2. Results

2.1 $^{159}$Ho

The level scheme of $^{159}$Ho proposed on the basis of in-beam experiments is given in fig. 1. Positions of 3/2$^+$ and 5/2$^+$ levels of 1/2$^+$[411] band are taken from table 1.

Table 1

<table>
<thead>
<tr>
<th>Rotational parameters of the bands in $^{159}$Ho.</th>
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<td>K</td>
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<tr>
<td>7/2$^-$[523]</td>
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<tr>
<td>7/2$^-$[523]</td>
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<tr>
<td>1/2$^+$[411]</td>
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<td>1/2$^+$[541]</td>
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Fig. 2. Proposed level scheme for $^{89}$Nb. Some states in even neighbours of $^{89}$Nb are shown for comparison.

pret the 13/2$^+$, 17/2$^+$ and 21/2$^+$ states as members of $p(9/2^-)^3$ multiplet, as it was done in the case of $^{91}$Nb).

The measured half-life of 2192 keV level is 15 ±5 nsec. Different hindrance factors $F = P_0 \exp(-\beta/p)$ (where $P$ is transition probability) correspond to different assumed multiplicities of 257 keV $\gamma$-rays. For the E1, E2 and M1 multiplicities, the $F_\gamma$-factors are $1.4 \times 10^{-6}$, $1.4$ and $9.4 \times 10^{-5}$, respectively (single proton transition probability $P_\gamma$ were calculated according to ref. 8). Both the $F(E1)$ and $F(E2)$ values fit the systematization given in refs. 7, 8). However, very low $F(M1)$ value jumps out from systematization given in ref. 9, by more than one order of magnitude and thus M1 assignment of 257 keV transition seems to be not justified.

Spins of the $^{89}$Nb excited levels above 2192 keV are generally greater than 19/2 as follows from their mode of de-excitation. The upper limit of spin values of $^{89}$Nb levels proposed here could be estimated from possibilities of the present experiment; i.e. maximum spin values so far observed is about 29/2. The results concerning $^{89}$Nb will be discussed in more detail in the prepered publication.

2.3 $^{197}$Tl

The reaction $^{197}$Au($^{3}$He,3n)$^{197}$Tl was used in the investigation of the excited states of nucleus $^{197}$Tl. The level scheme presented in fig. 3 was established on the basis of our earlier results 10). From the point of view of the simple shell model, it is difficult to interpret the low-lying isomeric state 9/2$^-$ which occurs also in other odd thalium isotopes. The ground
state with spin 1/2 and the first excited state with spin 3/2 can be interpreted as 3s1/2 and 2d3/2 shell model orbits. The 11/2\textsuperscript{−} level, due to the 1h11/2 orbit, is expected to be the low-lying isomeric state. The 9/2\textsuperscript{−} level produced by 1h9/2 orbit would be expected to lie at excitation energy \approx 3.3 MeV, since 1h9/2 orbit appears in the next shell. We performed a calculation according to Soloviev 11 in order to account for the influence of the blocking effect on the position of the 9/2\textsuperscript{−} state in 1971. This procedure leads to an excitation energy 2.3 MeV, which is still too high as compared with the measured values. This result supports an assumption of an oblate deformation, which lowers K=9/2 state originating from 1h9/2 shell orbit in desired way. Our values of the level spacings, spins and \(A_\nu\) of the related gamma-ray transitions and deexcitation modes concerning the levels at 608.5, 996.5, 1304.6, 1720.4 and 2042.0 keV support the idea of the rotational band on top of the 9/2\textsuperscript{−} state 10. This strengthens the assumption about a deformation of the state 9/2\textsuperscript{−}.

Cerolis mixing of states with \(\Delta K=1\) can explain the irregular spacings in the rotational levels. The application of the known rotational formula (1) gives the following values of the parameters \(E(K) = 6.37 \text{meV}, B=49.7 \text{keV}, A=258 \text{eV}, A_{2K} = 0.872 \text{meV}\) (The parameter C was not taken into account). The agreement by an order of magnitude of this value \(A_{2K}\) with the predicted value of 1.4 meV (assuming 12) shows that the level spacings are reasonable for this interpretation.

References

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