High Spin States in $^{106}$In

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High spin states have been investigated by the reaction $^{99}$Zr($^{19}$F, 3n), using an Anti-compton spectrometer device, for the nucleus $^{106}$In, for which no in-beam $\gamma$-spectroscopic information was available up to now. A level scheme has been constructed up to an $I^+ = (13, 14)$ state.

**Nuclear Reaction:** $^{99}$Zr($^{19}$F, xyy), $E = 62-82$ MeV; measured $E_\gamma$, $\gamma\gamma$-coincidences, $\gamma$-angular distributions. Deduced high spin states in $^{106}$In. Enriched target. Anti-compton spectrometer.

1. Introduction

Recently, considerable effort has been made to study the properties of even-even nuclei around the magic number 50 with $Z \leq 50$, $N \geq 50$ (e.g. [1-3]). There are, however, almost no investigations of odd-odd nuclei in this mass region, except two recent studies of $^{116}$In [4, 5].

The present work is part of an investigation of yrast lines in light nuclei near the closed shells $Z = 20$, $N = 20$, ($^{34}$Cl, $^{37}$Cl, $^{40}$K, $^{42}$Ca) and $Z = 28$, $N = 28$ ($^{55}$Fe, $^{56}$Fe) [6-8], $Z = 50$ [9] and of the $\beta^+$-decay of high spin isomers in neutron-deficient nuclei with masses $A \approx 100-110$ [10]. Results are given of an investigation of high spin states in $^{106}$In by the reaction $^{99}$Zr($^{19}$F, 3n). No in-beam $\gamma$-spectroscopic study on $^{106}$In existed up to now and the only information on this nucleus at present comes from $\beta$-decay work [11, 12].

While usually for even-even nuclei the data on the $\beta^+$-decay of the odd-odd parents yield a good starting basis for the interpretation of in-beam $\gamma$-spectroscopic results of heavy ion reactions, because in these cases low-lying high-spin states undergo $\beta$-decay (see, e.g. [10]), in the case of odd-odd nuclei the situation is less favourable. So, the even-even nucleus $^{108}$Sn decaying to $^{106}$In has in the ground state $I^+ = 0^+$ and, consequently, the $\beta$-decay populates only low-spin states in $^{106}$In.

The highest excited state in $^{106}$In known from $\beta$-decay [11] has $E^* = 1189.6$ keV and $I^* = 1^+$. This means that all states reached by $\beta$-decay have two-quasiparticle proton-neutron configurations, because collective states are expected in these nuclei at excitation energies $\geq 1.2$ MeV (see [13]). The $\gamma$-lines following the $\beta$-decay to low-spin states cannot be expected to be seen in an experiment exciting $^{106}$In by a high-spin selective heavy ion reaction. The identification of $\gamma$-transitions as belonging to $^{106}$In was made by excitation function measurements of the transitions and of the residual activity from the $\beta$-decay of $^{106}$In and by comparing both with statistical model calculations of the yields of the residual nuclei.

2. Experimental Procedure

Excitation functions, $\gamma\gamma$-coincidences and angular distributions have been measured for $\gamma$-transitions in residual nuclei produced in the reaction

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$^{90}$Zr($^{19}$F, x$\gamma$) at the MP-Tandem in Heidelberg. Three Ge(Li) detectors, one of them with an Anti-compton shield [14], with efficiencies of $\sim 27\%$ and an energy resolution of 2.1-2.3 keV were used. For calibration of the detectors in addition to the usual standard sources ($^{152}$Eu, $^{56}$Co, $^{228}$Th) also lines from Coulomb excitation of Au and lines of known relative intensity in $^{105,106}$Cd were used. The targets consisted of self-supporting metallic Zr-foils of 4.5 mg/cm$^2$, enriched in $^{90}$Zr to 97.7\% placed on a gold foil. The data have been taken on magnetic tape with a PDP-11/45 on-line computer in a multi-parameter event mode, the data evaluation was done on a DEC 10 computer. An example of a total projection spectrum taken with the Compton shielded detector is shown in Fig. 1. Examples of coincidence spectra gated with different lines of $^{106}$In are shown in Fig. 2. To correct for coincidences with the Compton background coincidence spectra obtained with gates set at both sides of the gate lines were subtracted. The excitation function has been taken in the range $E_{\text{lab}} = 62-82$ MeV in steps of 5 MeV. Gamma-gamma coincidences and angular distributions were measured at $E_{\text{lab}} = 72$ MeV. The angular distributions were taken with the Compton-shielded detector at 0°, 35°, 55°, 90°-in a distance target-Ge(Li) detector of 16 cm. They were normalized to transitions in $^{106}$Cd, $E_\gamma = 633$ and 861 keV, for which the angular distributions are well known [15]: $A_2 = +0.244(6)$, $A_4 = -0.0561(6)$ and $A_2 = +0.260(7)$, $A_4 = -0.056(8)$, respectively.

The intensities of the $\gamma$-transitions given in Table 1 and Fig. 6 were determined from singles spectra taken at 55° (the errors are $\sim 5-10\%$). The arguments to attribute $\gamma$-lines to transitions in $^{106}$In are as follows. We have performed a calculation of the