

THE LEVEL SCHEME OF ^{110}Ag FROM THE (n,γ) REACTION

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The investigation of the excited states of the doubly odd $^{110}_{47}\text{Ag}_{63}$ nucleus produced in the $^{109}\text{Ag}(n,\gamma)$ reaction has been performed using the experimental results from the previous papers^{1,2}.

Secondary gamma rays in the energy range 45 - 1200 keV were measured with the bent crystal spectrometers at Risö. The energy calibration were made using the 341.722(10) keV line from the $^{48}\text{Ti}(n,\gamma)$ reaction. The new measurements with the bent crystal spectrometers GAMS1 and GAMS2/3 at ILL Grenoble have been made in the energy range from 35 - 1800 keV and about 1070 transitions were found. For the energy calibration the 657.824(6) keV line from the decay³ of ^{110}Ag to ^{110}Cd was used. Intensities of the gamma transitions were normalized by the same decay line with 4.27 intensity /100 n. The last energy calibration has been made with a new energy value of 657.7622(21) keV⁴ and the results have been included into the level scheme fit.

The low-energy spectrum from 10 - 100 keV has been measured with Si(Li) detector (1 cm², $\Delta E = 300$ eV for $E_\gamma = 20$ keV) at LNPI in Gatchina. For the energy calibration were used energies of X - rays from Ag and In and the gamma rays energy values for Ag from the GAMS experiments. The efficiency calibration has been performed using gamma rays from the decay of ^{241}Am , X-rays from Ag and In and for the energies higher than 55 keV gamma rays from ^{110}Ag . These results were used for the intensity calibration of gamma lines with energies below 55 keV. A part of the spectrum is shown in fig. 1.

The spectra of the primary gamma rays from the thermal neutron capture were measured with the pair spectrometers at the ILL Grenoble and IKP Jülich in the energy range from 1380 to 8600 keV. The energy and intensity calibration were made with Al (n,gamma) reaction lines. In the primary spectra the 6805.47(8) keV line was a not resolved doublet of two transitions populating ground 1^+ and first excited 1.1 keV 2^- states. This was evidently from the 0.89(8) keV value ($B_n - E_{tr}$) and the halfwidth was 16% higher for the measured line.

The conversion electron spectrum from ^{110}Ag was studied with the spectrometer BILL at ILL Grenoble. In the energy range from 20 to 650 keV about 580 electron lines were found. The target was prepared by evaporation of 99.9% enriched ^{109}Ag onto an Al foil. The intensities of the electron lines were normalized to the absolute conversion electron intensities of 117.60 keV (K, L_1 , L_2 , L_3 , M_1) and 118.71 keV (K, L_1 , L_2 , L_3) lines from the $^{109}\text{Ag}(n,\text{gamma})$ reaction and ^{110}Ag decay 657.82 keV (K) line with E1, E2 and E2 multipolarities, respectively.

Prompt $\gamma\gamma$ coincidences were studied with the two Ge(Li) (1 cm^3 and 5 cm^3 , the resolution of 0.7 and 1.0 keV for $E_\gamma = 100\text{ keV}$) detectors. Coincidence events were registrated like a matrix with 1024 x 2048 channels in the energy range 15 - 240 and 40 - 640 keV, respectively. For the evaluation of the coincidence matrices the method described in ref. 5 was used. The sensitivity of the $\gamma\gamma$ coincidence spectrometer at Gatchina is shown in fig. 2.

At IKP in Jülich $\gamma\gamma$ coincidence measurements were performed with the matrix of 4096 x 4096 channels in the energy range from 50 - 300 and 80 - 2000 keV, respectively.

The delayed coincidence and singles experiments to investigate the population of the 118.7 keV isomeric state ($T_{1/2} = 36.8(7)\text{ ns}$) performed in Belgrade with Ge(Li)-NaI(Tl) detectors resulted in about 600 gamma lines in the energy interval from 100 - 1200 keV. First the single spectrum has been measured with the Ge(Li) detector with resolution of 0.70 keV and 4.0 keV at 122 keV and 500 keV, respectively. The NaI(Tl) detector was used to select the 117.60 keV and 118.71 keV transitions depopulating the isomeric state. The ratio of coincidence and single intensities for each transition, normalized to 100 for the transition directly populating the 118.7 keV isomeric level, gives the parameter characterized by the share in the feeding of the isomeric state.

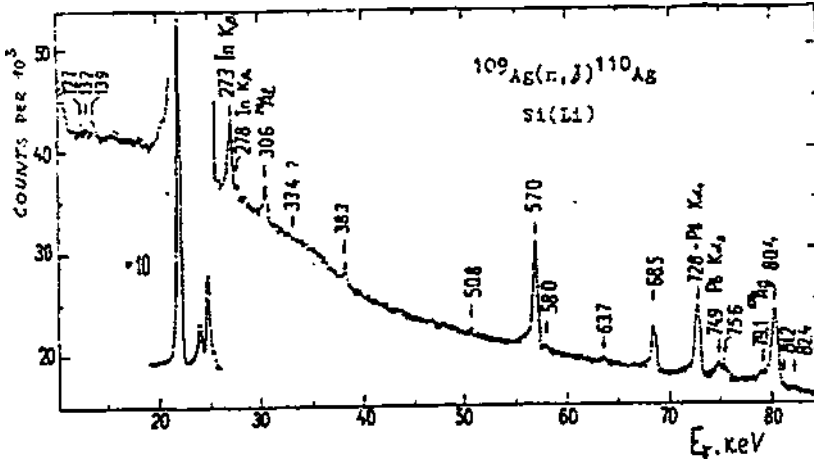


Fig. 1. The low-energy γ -ray spectrum.

From all extensive experimental data and (d,p) reaction data⁶ the level scheme has been constructed up to 1.2 MeV excitation energy with 83 levels (13 of them are new) and among 1141 measured transitions 553 of them were placed into the level scheme.

Into the level scheme were included the $\gamma\gamma$ coincidence data made at LNPI in order to investigate the population of the isomeric 117.55 keV state ($T_{1/2} = 250.4$ days, 6^+). The group of very strong gamma transitions of 57.01, 80.44, 191.55, 104.78, 110.49, 132.72, 167.06, 232.63 and 302.84 keV were found in cascades without any amount of $\gamma\gamma$ coincidences with other transitions already placed into the level scheme. From the gamma lines found in cascades the new states were found at energies: 174.57, 255.01, 446.57, 551.35, 557.06, 579.29, 613.63, 789.69 and 881.51 keV (Fig. 3).

The level energies with spin and parity assignments are listed in Table 1.

Some of the proton-neutron multiplets are identified. The ground state 1^+ following by the other 6^+ at 117.5 keV, 5^+ at 174.6 keV, 4^+ at 255.0 keV, 2^+ at 198.7 keV states the configuration is ($\pi 7/2^+$, $\nu 5/2^+$).

Table

Eex (keV)	I^{π}	Eex (keV)	I^{π}
0	1^+	640.259(5)	$2^+, 3^+, 4^+$
1.113(2)	2^-	653.848(2)	$1^-, 2^-$
117.532(5)	6^+	663.405(4)	$1^+, 2^+, 3^+$
118.710(2)	3^+	664.865(2)	$1^-, 2^-$
174.547(5)	$5^+, 6^+$	683.085(7)	$1^+, 2^+, 3^+$
191.613(4)	$2^+, 3^+$	689.109(3)	$1^+, 2^+, 3^+$
198.676(2)	2^+	689.162(2)	$2^-, 3^-$
236.833(1)	$1^-, 2^-, 3^-$	698.485(2)	$1^+, 2^+$
237.027(2)	$1^-, 2^-$	706.062(2)	$1^+, 2^+$
254.992(3)	$4^+, 5^+$	725.738(2)	$1^-, 2^-$
267.195(2)	$1^+, 2^+$	741.596(2)	$2^+, 3^+$
267.230(4)	$1^+, 2^+, 3^+$	748.506(3)	$1^+, 2^+$
271.451(2)	$2^+, 3^+, (4)$	753.273(2)	$2^+, 3^+$
304.503(2)	$(1)^+, 2^+, 3^+$	759.550(4)	$1^-, 2^-$
338.884(3)	$1^-, 2^-$	766.963(3)	$2^+, (1)^+$
360.587(2)	$1^+, 2^+$	773.584(3)	$1^+, 2^+$
379.365(7)	$1^+, 2^+, 3^+$	785.569(2)	$2^+, (1)^+$
381.161(1)	$1^-, 2^-$	789.628(2)	$1^-, 2^-, 3^-$
424.661(3)	$1^-, 2^-$	811.329(2)	$1^+, 2^+$
432.328(3)	2^-	818.790(5)	$1^-, 2^-, 3^-$
446.529(2)	$3^-, 4^-$	818.886(4)	$1^+, 2^+, 3^+$
468.807(2)	$2^+, 3^+$	820.640(8)	$1^-, 2^-$
471.199(3)	$1^+, 2^+, 3^+$	854.332(5)	$1^-, 2^-$
485.728(2)	$2^+, 3^+$	880.444(3)	$(1, 2, 3)$
496.833(3)	$1^-, 2^-$	881.422(4)	$1^-, 2^-$
525.612(1)	$1^-, 2^-$	910.815(2)	$2^+, 3^+$
527.461(4)	$2^+, 3^+$	925.035(5)	$(1, 2, 3)$
536.130(2)	$0^+, 1^+, 2^+$	953.096(3)	$1^+, 2^+$
539.525(4)	$1^-, 2^-, 3^-$	954.314(2)	$1^+, 2^+$
539.760(4)	$1^+, 2^+, 3^+$	979.724(5)	$(1, 2, 3, 4)^+$
549.328(2)	$1^+, 2^+$	985.576(3)	$1, 2$
551.309(2)	$2^-, 3^-$	994.969(3)	$1^+, 2^+$

557.014(2)	$2^-, 3^-$	1012.956(3)	$1^+, 2^+$
579.241(2)	$2^-, 3^-$	1034.821(3)	$1^+, 2^+$
589.722(4)	$1^-, 2^-$	1036.792(4)	2,3
592.856(2)	$2^+, 3^+$	1097.429(2)	$1^+, 2^+$
594.968(3)	$1^-, 2^-$	1106.637(3)	$1^+, 2^+$
605.149(2)	$2^-, 3^-$	1164.354(8)	1,2,3
613.582(2)	$2^-, 3^-$	1169.006(3)	$1^+, 2^+, 3^+$
615.071(1)	$1^-, 2^-$	1175.735(4)	1,2,3
633.384(1)	$0^-, 1^-, 2$	1178.251(6)	2,3

The 1.11 keV level is probably the 2^- state of the proton-neutron doublet ($\pi p_{1/2}^-, \nu d_{5/2}^+$) $^{2^-, 3^-}$. We have tried to identify the higher lying proton-neutron multiplets.

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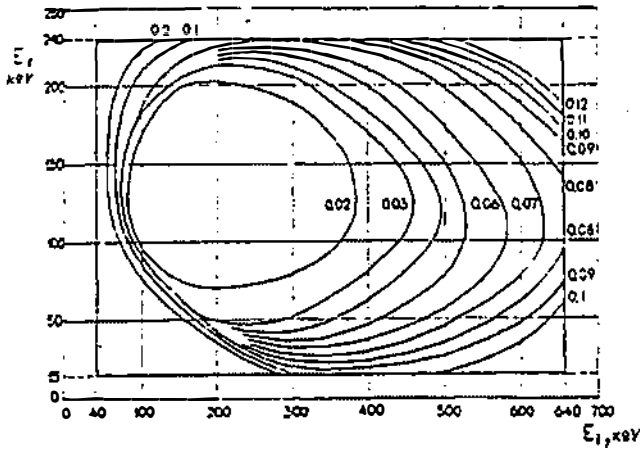


Fig. 2. Sensitivity of coincidence spectrometer (Leningrad)

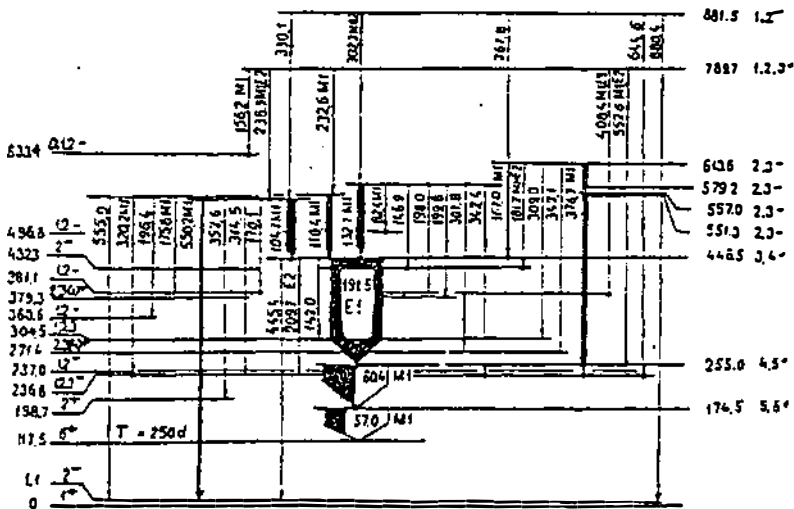


Fig. 3. A part of ^{110}Ag level scheme connected with the population of the 117.5 keV isomeric state.