THE LEVEL SCHEME OF ^{140}La

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The level scheme of $^{140}_{57}La_{83}$ has been established using the previous data summarized in Nucl. Data Sheets[1] and the present experimental results from the (n,γ) reaction.

At the High-Flux Reactor of the ILL in Grenoble the secondary γ-rays in the energy range from 30 - 1200 keV and the conversion electrons from 20 - 1000 keV have been measured with the curved crystal spectrometers GAMS1 and GAMS2/3 and the electron spectrometer BILL, respectively.

The energies and intensities for 208 transitions in ^{140}La have been obtained and the multipolarities for 40 of them have been found.

At DIDO reactor in Jülich, the single γ-ray spectrum has been measured up to 70 keV in order to obtain unobserved lowenergy transitions from the decay of the 63 keV 4^- and 49 keV 6^- states in ^{140}La. Both states are populated from the 3^+, 4^+ thermal neutron capture state. The new 14.18(8) keV gamma line was found corresponding to the 100% transition from the 48.9 keV 6^- state to the 34.7 keV 5^- state. Assuming the pure M1 character for this transition one could obtain the total transition intensity as 20±4/100n in agreement with the total population of the 48.9 keV state. The transition of 26.60 keV placed between the 602.0 and 575.5 keV states in the preliminary level scheme[2] now is omitted because the observed intensity for this line corresponds to the Ge K_β escape peak of the 37.8 keV line. The new observed 49.723(23) keV transition is placed between 322 keV 5^- and 272 keV 4^- levels.

The $\gamma\gamma$ coincidence experiment for high and low energy γ-rays has been made at IBK in Vinča.The results of the measurements are shown in the Table 1. They were obtained using a filtered external horizontal neutron beam emerging from the reactor with a thermal neutron flux of 2×10^7 n $cm^{-2}sec^{-1}$. The coincidence facility used several Ge(Li) detectors. So, in the high energy - low energy $\gamma\gamma$ coincidence measurements a combination of 15 cm^3 and 25 cm^3 and in the low energy coincidences 15 cm^3 and 40 cm^3 detectors were combined. The minimum resolving time of the fast - slow coincidence system was 1.5 μs.

Table 1. Observed $\gamma\gamma$ coincidence relationships in ^{140}La

Gate transition (keV)	(Level)	Coincidence transitions (keV)
156.6	(318)	118.9, 162.7, 356.4 + 356.8, 426.5, 478.0
162.7	(162)	155.6, 169.2 + 169.4, 304.8, 324.3 + 324.7, 412.6, 495.6, 549.0
218.2	(322)	169.1 + 169.4, 280.0, 291.0, 310.2, 324.3 + 324.7, 356.4 + 356.8, 381.8, 422.7, 589.6 + 591.6, 4416.4
288.3	(318)	169.1 + 169.4, 426.5, 478.0
422.7	(745)	218.2, 237.7, 258.9, 272.3, 288.3
4389.7	(771)	169.1 + 169.4, 567.4, 667.6, 708.2, 737.0
4416.4	(745)	155.6, 162.7, 218.2, 237.4, 272.3 288.2, 422.6, 426.5, 640.9, 696.0, 710.1
4449.3	(712)	162.7, 549.3
4502.8	(658)	162.7, 218.2, 280.0, 495.6, 567.4, 595.1, 602.0, 623.6, 628.3, 658.3
4559.1	(602)	218.2, 280.0, 538.8, 553.1, 567.4, 602.0
4842.8	(318)	155.5, 162.7, 237.7, 272.3, 288.3
4888.8	(272)	209.2, 237.7, 272.3

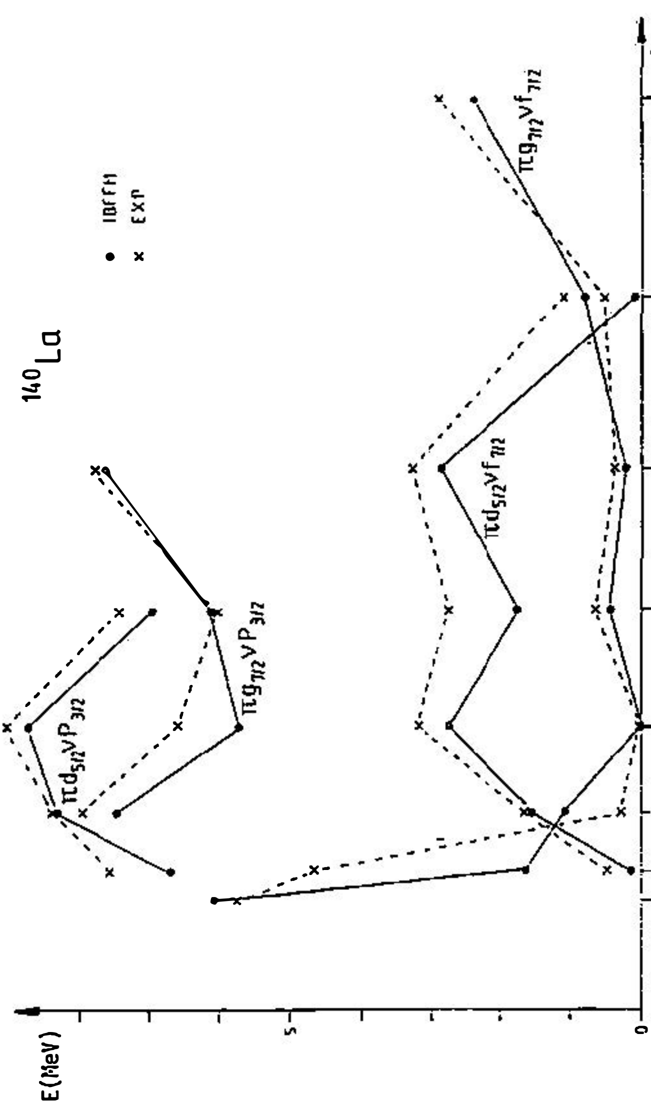
The line of the 169.14(4) keV is placed between the 744.7 and 575.5 keV levels and the 913 keV level from the previous paper was omitted because the $\gamma\gamma$ coincidence results could not support this level.

The level scheme involves 38 levels up to 1.1 MeV excitation energy (7 levels are new) and 155 transitions are placed into the level scheme. From the primary transition energies and the derived level energies the neutron binding energy was deduced to be 5161.07+0.10 keV. The level energies with spin and parity assignments are listed in Table 2.

The level scheme involves 37 levels up to 1.1 MeV excitation energy (7 levels are new) and 156 transitions were placed into the level scheme. From the primary transition energies and the derived level energies the neutron binding energy was deduced to be 5161.07 ± 0.10 keV. The level energies with spin and parity assignments are listed in Table 2.

On the basis of the beta decay[2,7], (d,p) reaction[3] and present results[6] the states at 581(0^-), 467(1^-), 30(2^-), 0(3^-), 63(4^-), 35(5^-), 49(6^-) and 285(7^-) are assigned to the $\pi g_{7/2},\nu f_{7/2}$ multiplet configuration. The states at 44(1^-), 163(2^-), 318(3^-), 272(4^-), 322(5^-), 104(6^-) are assigned to the $\pi d_{5/2}$, $\nu f_{7/2}$ multiplet. The states at 796(2^-), 658(3^-), 602(4^-) and 771(5^-) can be assigned to the $\pi g_{7/2}$, $\nu p_{3/2}$ multiplet, the states at 755(1^-), 831(2^-), 912(3^-) and 744(4^-) might belong to the $\pi d_{5/2}$, $\nu p_{3/2}$ multiplet.

The IBFFM[4,5,7] calculation in a model space with protons $g_{7/2}$ and $d_{5/2}$ and neutrons $f_{g7/2}$ and $p_{3/2}$ support these assignments. Calculation shows that the wave functions of 1_1^- and 1_2^- states and 2_1^- and 2_1^- states are rather mixed. In Fig.1 the classification of the IBFFM levels into multiplets with largest components in the wave functions. The experimental levels of ^{140}La are compared with the theoretical spectra on the basis of level energies, electromagnetic deexcitation, and transfer properies. IBFFM and experimental levels are presented by solid circles and triangles, respectively.



E(MeV)
5
0
^{140}La
• IBFFM
× EXP
$\pi d_{5/2}\nu p_{3/2}$
$\pi g_{7/2}\nu p_{3/2}$
$\pi d_{5/2}\nu f_{7/2}$
$\pi g_{7/2}\nu f_{7/2}$
0
1
2
3
4
5
6
7
I

Fig. 1.

Table 2.

E_{ex} (keV)	I^{π}	E_{ex} (keV)	I^{π}
0˙	3^-	711.715(8)	2^-, 3^-
29.964(1)	2^-	744.717(3)	$4^-(5)^-$
34.646(1)	5^-	754.826(19)	1^-, 2^-
43.824(8)	1^-	771.437(4)	5^-
48.884(3)	6^-	796.248(8)	2^-
63.179(1)	4^-	830.895(13)	2^-, 3^-, $(4)^-$
103.828(3)	6^-	905.754(15)	2^-
162.678(1)	2^-	912.165(8)	3^-, 4^-
272.338(2)	4^-	917.535(11)	2, 3, 4^-
284.673(8)	7^-	941.751(21)	2^-, 3^-, 4^-
318.256(9)	3^-	968.660(63)	3^-, 4^-
322.056(3)	5^-	986.700(15)	4^-, 5^-
467.533(18)	1^-	1035.664(11)	4^-
575.539(9)	2^-, 3^-	1055.067(6)	4^-, 5^-
581.283(145)	0^-	1093.577(54)	2^-, 3^-, 4^-
592.109(29)	2^-	1100-941(19)	3^-, 4^-
602.009(3)	4^-	1109.769(24)	3^-, 4^-
658.261(4)	3^-	1116.804(17)	2^-... 5^-
673.020(12)			

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