ISOMERIC CROSS-SECTION RATIOS AND TOTAL CROSS-SECTIONS FOR THE ^{113}In$(n, 2n)^{112g,m}$In AND ^{115}In$(n, 2n)^{114g,m}$In REACTIONS

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The isomeric ratios and excitation functions were measured for the ^{113}In $(n, 2n)$ ^{112g,m}In and ^{115}In $(n, 2n)$ ^{114g,m}In reactions in the neutron energy range from 13.1 Mev to 18.2 Mev.

The results are compared with the statistical-model predictions. Use was made of modified nuclear level density formulae based on superconductivity theory, which account for the pairing and shell effects.

1. *Introduction*

The application of the nuclear level density based on the superconductivity model [1] for calculating the cross-section ratios and total cross-sections was presented in Ref. [2, 3]. To collect more experimental material for confirming the correctness of the description of isomeric ratios by the superconductivity model the cross-sections for the ^{113}In $(n, 2n)^{112g,m}$In and ^{115}In$(n, 2n)^{114g,m}$In reactions were measured in the neutron energy range from 13.1 Mev to 18.2 Mev. The results obtained were compared with the statistical model predictions calculated as in Ref. [2].

2. *Experimental procedure*

Samples of spectrally pure indium were irradiated with neutrons obtained in the ^{3}H$(d, n)^4$He reaction. The deuterons were accelerated in a 3 Mev Van de Graaff accelerator. The changes of the neutron flux during irradiation were determined by counting in a CsI scintillator the protons recoiled from a polyethylene foil.

The gamma activity of the irradiated samples was measured using the spectrometer with a single 3×3 inch. NaI(Tl) crystal. The photo-peak efficiencies of the spectrometer were taken from tables of Crouthamel [4]. The β^- were measured using a GM counter. In the case of the ^{113}In$(n, 2n)^{112g,m}$In reaction the 14.3 m and 20.7 m β^+ activities allowed to determine the isomeric ratio by measuring the annihilation quanta. The cross-section σ_m for the population of the metastable state was measured relative to the known cross-section

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of the $^{64}Zn(n, 2n)^{63}Zn$ reaction. Having σ_m and the isomeric ratio the total cross-section was determined.

In the case of the $^{115}In(n, 2n)^{114g,m}In$ reaction σ_m was determined by measuring the 51d activity of the 191 keV γ-rays relative to the cross-section of the $^{204}Pb(n, 2n)^{203}Pb$[5] reaction. The attenuation of the gamma rays in the samples was taken into account. The σ_g cross-section for the population of the ground state was determined by measuring the $72s-\beta^-$ activity refering to the $51d-\beta^-$ activity resulting from the decay of the ^{114m}In state.

3. *Results*

The results of measurements of the isomeric ratios and total cross-section are shown in Table I and in Figs from 1 to 4. The experimental errors are statistical errors only. The neutron energy spread was determined according to the method described in Ref. [2].

TABLE I

Isomeric ratios and cross-sections for the $^{113}In(n, 2n)^{112g,m}In$ and $^{115}In(n, 2n)^{114g,m}In$ reactions

E_n (MeV)	$^{113}In(n, 2n)^{112g,m}In$		$^{115}In(n, 2n)^{114g,m}In$	
	σ_g/σ_m	σ_{tot}(mb)	σ_g/σ_m	σ_{tot}(mb)
12.98±0.15	0.23±0.06	1369±137	0.191±0.011	1394±166
13.33±0.10	0.13±0.01	1356± 68	0.155±0.003	1623± 68
13.86±0.09	0.15±0.01	1503± 74	0.173±0.003	1748± 82
14.52±0.12	0.06±0.01	1527± 56	0.191±0.003	1805±218
15.15±0.14			0.225±0.004	1727± 78
15.17±0.14	0.06±0.01	1557± 37		
15.44±0.16		1725± 49	0.173±0.003	1670±73
15.95±0.19				1745±178
15.98±0.19	0.10±0.02	1489± 99		
16.28±0.16	0.13±0.02	1377±101		
16.59±0.09			0.188±0.015	1785±273
16.86±0.25			0.188±0.009	1794±186
16.87±0.25	0.17±0.04	1462±219		
17.35±0.24			0.185±0.017	1929±298
17.37±0.24	0.16±0.03	1408±158		
17.82±0.17			0.147±0.009	2014±326
17.83±0.13	0.14±0.02	1445±139		

The results of the isomeric ratios for the $^{113}In(n, 2n)^{112g,m}In$ reaction confirm the single measurement at $E_n = 14.7$ MeV done by Rötzer [7] who obtained the value $\frac{\sigma_g}{\sigma_m} = 0.2$. The result obtained in Ref. [6] is much higher.

The total cross-section values presented in Ref. [6] and Ref. [7] agree within the experimental errors with our measurements.

Results for the $^{115}In(n, 2n)^{114g,m}In$ reaction agree well with the isomeric ratio for 14.7 MeV neutrons given in Ref. [6] and Ref. [7] and with the cross-sections measured by Prestwood and Bayhurst [8] but differs considerably from those obtained by Menlove *et. al.* [9].

4. *Comparison of the experimental results with the statistical theory*

The theoretical calculations were performed according to the statistical method described in details in Ref. [2]. The optical model transmission coefficients were taken from the tables of Mani, Melkanoff and Iori [10].

Because of the high excitation energies involved in both reactions the level density was used for describing the excited states. The nuclear level density was calculated using the superconductivity model. This model refers to doubly even nuclei. For an odd-odd or odd-mass nucleus the excitation energy was shifted in the way presented in chapter 5 of Ref. [3].

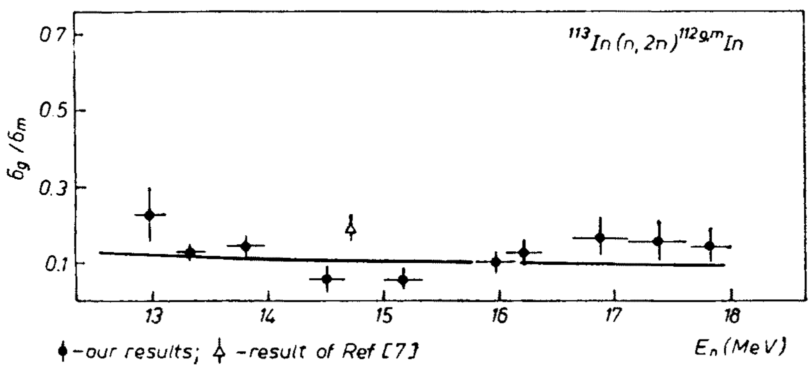

Fig. 1. The isomeric ratios for the ^{113}In $(n, 2n)$ ^{112g,m}In reaction. The solid line presents the statistical calculations based on the superconductivity model of the level density

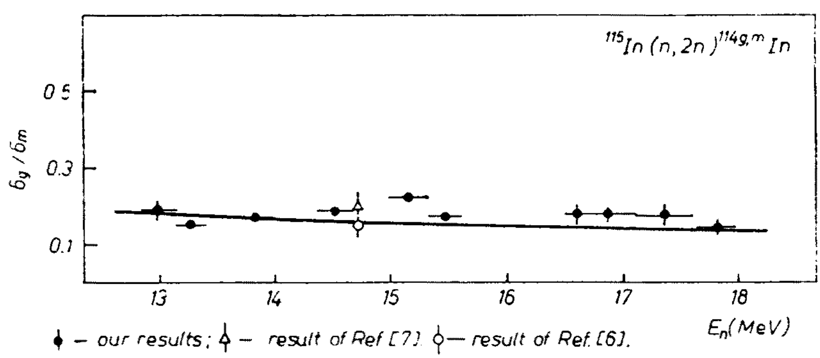

Fig. 2. The isomeric ratios of the ^{115}In $(n, 2n)$ ^{114g,m}In reactions. The solid line presents the statistical calculations

Figs 1 and 2 present the measured and the calculated isomeric ratios for the ^{113}In$(n, 2n)$ ^{113g,m}In and ^{115}In$(n, 2n)^{115g,m}$In reactions, respectively. The theoretical results (solid lines) describe correctly the measured values. The systematical enhancement of the theoretical total cross-sections over the experimental ones (Figs 3 and 4) is less pronounced here as in the cases of $(n, 2n)$ reactions on lighter target nuclei [2, 3]. This behaviour could indicate that the competition between the emission of the second neutron and gamma deexcitation in the excitation energy region near to the threshold for the emission of the third neutron (about 17.5 MeV for the reactions considered) is less important.

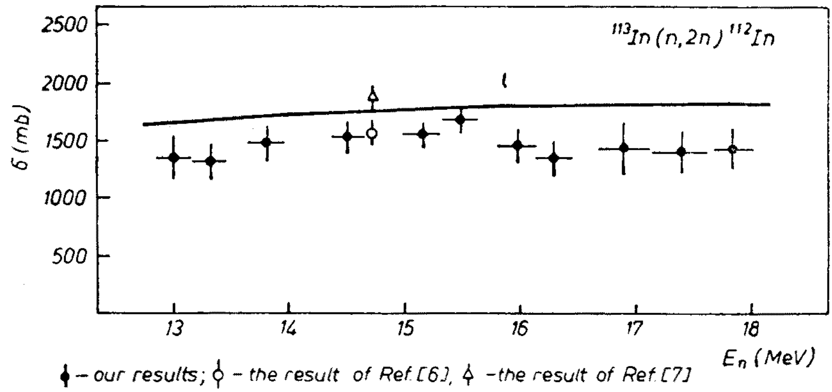

Fig. 3. The cross-sections for the ^{113}In $(n, 2n)$ ^{112g,m}In reaction. The solid line presents the statistical calculations

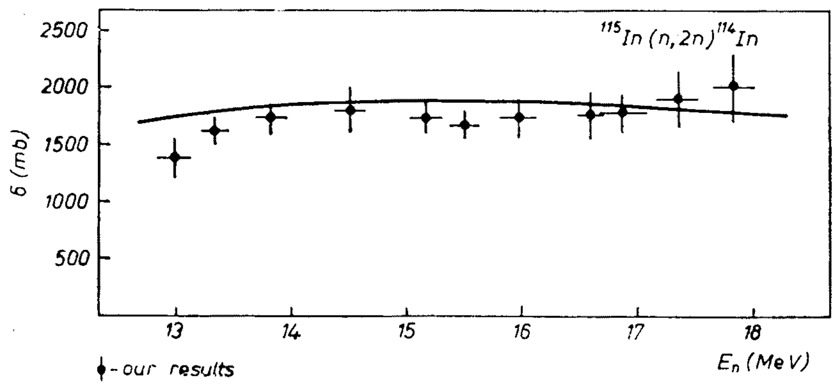

Fig. 4. The cross-sections for the ^{115}In $(n, 2n)$ ^{114g,m}In reaction. The solid line presents statistical calculations

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