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Abstract

New level schemes up to 3 MeV are constructed for ^{111,113}Cd on the basis of (n,n'γ) and (n,γ) experiments of Baskova *et al.* More than 40 new levels are introduced in both nuclides in the 1/2-15/2 spin range. Numerous new spin, parity, and multipole mixing ratio values are reported. Antialigned unique-parity states emerging from the coupling of an $h_{11/2}$ neutron to core excitations up to 6^+ spin are identified in both nuclides. The B(E2) values of the $7/2^-_1 \rightarrow 11/2^-_1$ transitions in $^{109-119}$Cd are found to fit a parabola, in contrast to the predictions of the triaxial-rotor-plus-particle model. A group of isolated positive parity states with a decreasing spin sequence, which fulfil the criteria to be intruder states, is also identified. The symmetric particle-plus-rotor model is found to be able to reproduce only a narrow class of levels in ^{111,113}Cd. States of $g_{7/2}$ and $h_{11/2}$ parentage exhibit collective nature, in contrast to those of $d_{3/2}$ and $d_{5/2}$ parentage. Theoretical reproduction of antialigned states of both parities turned out to be problematic. The disputed location of the lowest-lying photoactivation levels of ^{111}Cd is clarified. The binding energy of the last neutron is deduced to be 6975.9(2) keV and 6542.0(2) keV in ^{111}Cd and ^{113}Cd, respectively.

Zustände mit niedrigen Spins in $^{111,113}Cd$

Zusammenfassung

Für die Nuklide $^{111,113}Cd$ wurden neue Niveauschemata bis zu einer Energie von 3 MeV aufgestellt, die auf den (n,n'γ) und (n,γ) Experimenten von Baskova *et al.* basieren. In beiden Kernen wurden mehr als 40 neue Niveaus zugeordnet mit Spin Werten im Bereich zwischen 1/2 und 15/2. Es werden zahlreiche neue Werte für Spins, Paritäten und Multipol-Mischungsverhältnisse berichtet. Antialigned unique-parity-Zustände, die aus der Kopplung eines $h_{11/2}$- Neutrons mit Rumpfanregungen bis zu Spin 6^+ stammen, wurden in beiden Isotopen identifiziert. Die B(E2) Werte der Übergänge $7/2^-_1 \rightarrow 11/2^-_1$ in $^{109-119}Cd$ lassen sich durch eine Parabel anpassen, im Widerspruch zu den Vorhersagen des dreiachsigen Teilchen-plus-Rotor-Modells. Eine Gruppe isolierter Zustände mit positiver Parität und fallender Spinfolge, die die Eigenschaften von Intruder-Zuständen haben, wurde identifiziert. Das symmetrische Teilchen-plus-Rotor-Modell kann nur einen engen Bereich von Zuständen in $^{111,113}Cd$ wiedergeben. Zustände, die von $g_{7/2}$ - und $h_{11/2}$ - Niveaus stammen, zeigen kollektive Natur, im Gegensatz zu denen, die von $d_{3/2}$ - und $d_{5/2}$ - Niveaus herrühren. Es war problematisch, Antialigned-Zustände mit theoretischen Modellen wiederzugeben. Die fragliche Lage der niedrigsten, durch Photoanregung erreichbaren Zustände in ^{111}Cd wurde geklärt. Die Bindungsenergie des letzten Neutrons wurde in ^{111}Cd zu 6975.9(2) keV und in ^{113}Cd zu 6542.0(2) keV bestimmt.

Content

I. Introduction

A laboratory report dealing with (n,n'γ) and (n,γ) studies of ^{111,113}Cd was published recently by Baskova *et al.*[1] The authors reported many new transitions and multipole mixing ratios but they made only a few efforts to interpret them. Numerous intense transitions were not placed and there was a little progress in the development of the level scheme. Moreover, a part of the placements done by Baskova *et al.*[1] seems to be incorrect. The aim of this paper is the thorough analysis of the extensive experimental data published in Ref. 1. We note that the authors[2] of the updated relevant Nuclear Data Sheets' displayed but did not evaluate critically these data.

A second motivation is to make progress in the identification and characterisation of the photoactivation levels of ^{111}Cd. Recently we summarised the available data[3] which are based on the the measurements of Boivin *et al.*[4] and Chertok and Booth[5]. We tried to identify the levels reported by them with levels known from other nuclear reactions[3]. The identification was not completely successful and, moreover, an activation level different from those observed by Boivin *et al.*[4] and Chertok and Booth[5] was reported by Anderson *et al.*[6]

The medium-weight odd Cd-isotopes, unlike the odd Ag and In isotopes, have not been exhaustively investigated theoretically. The only extensive study was performed by Wang *et al.*[7], who interpreted the level scheme of ^{111}Cd on the basis of the symmetric particle-plus-rotor model. They supposed a slight ($\delta \sim 0.10$) prolate deformation and, by comparing their experimental and theoretical level scheme, concluded that ^{111}Cd exhibits rotational phenomena. The measured and calculated branching ratios, however, are in conflict with each other in some cases. Interpretation of some levels, observed by them, as collective states seems also questionable. The investigation of the validity of the rotational interpretation is a part of the subject of this work.

II. Experimental techniques

Since Ref. 1 is written in Russian we shortly summarize the available information on the experimental techniques used by Baskova *et al.*[1] We consider Ref. 8 too, where they report in a journal a minor part of their results concerned to the ^{110}Cd(n,γ) study. The experiments were performed at two horizontal channels of the IR-8 reactor of Kurchatov Institute, Moscow. The neutron beam for the (n,n'γ) irradiations was filtered with 1 mm Cd, 1 gcm^{-2} B_4C, 50 mm U and 1 gcm^{-2} ^{10}B. The same filters, except ^{10}B, were used when high-energy gamma-rays (E>4.5 MeV) following neutron capture were investigated. ^{110}Cd(n,γ) studies were undertaken at the tangential channel as well where the number of fast neutrons was 20 times lower than in the horizontal channels. In the latter case the applied filters were 1 mm Cd, 1 gcm^{-2} B_4C, 50 mm Pb, and 1 g cm^{-2} ^{10}B.

Metallic $^{110-113}$Cd samples of 30, 15, 19, and 13 g respective weights enriched to ~96% in the studied isotope were investigated. Two unspecified Ge detectors were used: one, which had 10% efficiency, at the horizontal channels and another, with 20% efficiency at the tangential channel. Our impression is that their resolution was moderate since numerous multiplets remained unresolved. The authors performed angular distribution measurements as well.

The data referring to ^{113}Cd are incomplete, probably because of the death of the principal investigator. Secondary γ-rays from ^{112}Cd(n,γ) reaction were not reported at all. In the list of the γ-rays observed in (n,n'γ) experiment there are wide energy regions where no transitions were reported, evidently not from nuclear physical grounds. Because of these reasons sometimes we had to draw quite speculative conclusions. The ^{111}Cd data are complete and especially the investigation of the (n,n'γ)/(n,γ) intensity ratios has turned out to be effective when introducing new levels.

III. Data treatment

In an endeavor to publish primer data we consider the γ-transition energies and intensities reported only by Baskova *et al.*[1] when calculating the level energies and populations. On the other hand, making the information on the level scheme of ^{111,113}Cd as complete as possible, levels not seen by Baskova *et al.*[1] but known from other nuclear reactions are incorporated to Tables I and II, where the results are shown. Following the practice employed in Nuclear Data Sheets we indicate the reaction types which excite the individual levels. The methods of the evaluation are as follows.

a/ Introduction of new levels

We introduce a new level when find at least three transitions which populate or depopulate it. In some cases, however, when we have other evidences accept new levels without finding three connecting transitions.

b/ Level energies

The level energies are calculated by using the γ-transition energies found in Ref. 1. The only considered "external" datum is the literature value[9] of the first $11/2^-$ (isomer) state of ^{111}Cd, which is 396.22(3) keV. We accepted it in order to decrease the error propagation in the energy of the negative parity states. The value given by Baskova *et al.*[1] is 396.17(23) keV which agrees with the literature but far less precise.

The level energies listed in Table I and II are weighted averages of the individual energy values obtained by using the Ritz combination principle. The uncertainties are quadratically summed. When placing a transition between two levels, agreement of the energy difference with the transition energy within one standard deviation is required. In the case of ^{111}Cd when level energies from both (n,γ) and (n,n'γ) measurements are reported only the more accurate values, which usually were the (n,n'γ) data, are taken into account.

c/ Spin and parity assignments

We make our spin-parity assignments by considering not only the results of Baskova *et al.* but the literature data as well. Some assignments are deduced from the systematics. In the case of ^{111}Cd a spin indication is the (n,n'γ)/(n,γ) intensity ratio.

An important source of the assignments is the own angular distribution measurements of Baskova *et al.* Moreover, they reported a_2 and a_4 values for 22 unplaced transitions. Since we managed to place most of them in the decay scheme we performed angular distribution calculations by means of the CINDY code[10] to obtain spin-parity values for the levels depopulated by these transitions. Our efforts usually led to unambigous assignments.

IV. Results and discussion

1. ^{111}Cd

The level structure of ^{111}Cd has been investigated by β-decay experiments[11-13], Coulomb excitation by light (CELI)[14-17] and heavy ions (CEHI)[18], (d,p) and (d,t)[19], (^{3}He,2nγ)[7], (α,3nγ)[20], (d,d')[21], (p,p')[22] and (γ,γ')[4-6] reactions. Benczer-Koller *et al.*[23] measured g-factors of the lowest-lying levels. The results for the levels of ^{111}Cd are summarized in Table I. We discuss below the levels which have special importance or for which there is a considerable amount of new information not indicated in Table I. We show below that nearly all states of ^{111,113}Cd have a mixed configuration. This point is important for understanding the configurations of the individual levels. The "suggested configurations" are the proposed *dominant* ones. There may be a considerable admixture of other configurations.

0.0, 245.4, 396.2, and 416.7 keV levels

These are the first $1/2^+$, $5/2^+$, $11/2^-$, and $7/2^+$ levels, respectively, which are well known from the literature[7,9,18]. They are predominantly single particle states but in the case of the positive parity ones a considerable configuration mixing is observable. Its clearest indication is the fragmentation of the single particle strengths in (d,p) reaction. These states carry only about a half of the relevant single particle strengths. Another evidence is that the small negative magnetic moment of the ground state is explainable only if $d_{5/2}$ and/or $d_{3/2}$ admixture is supposed[18].

342.1 keV level

This level was interpreted by Wang *et al.*[7] and by Vetter[18] as the second member of the $1/2^+$[411] band. This interpretation is obviously incorrect. When adding pairs of neutrons the corresponding states rapidly lower (342.1 keV - 298.6 keV - 229.1 keV - 135.4 keV - 26.9 keV) and at ^{121}Cd it becomes to be the ground state. This fact, as well as the large cross section observed in (d,p) reaction[19] suggest a predominant $d_{3/2}$ single particle character. The relatively high B(E2) value found in Coulomb-excitation experiments[14-17], however, indicates configuration admixture and some collectivity. It is very probable that the $2^+_1 \otimes s_{1/2}$ wave function really contribute to the total wave function of this state. On the other hand, the 866.6 keV level, which is thought to be the $3/2^+$ member of the $2^+_1 \otimes s_{1/2}$ doublet, carries a considerable part of the $d_{3/2}$ single particle strength.

620.2 keV level

This level has been populated in a variety of reactions[1,7,9,18]. The 203.29 keV transition was observed by Baskova *et al.* for the first time. This is the first observation of the $5/2^+_2 \rightarrow 7/2^+_1$ transition in an odd Cd isotope. We confirm the suggested[18,7] $2^+_1 \otimes s_{1/2}$ configuration, which is also supported by the g-factor measurement of Benczer-Koller *et al.*[23] (See also the discussion of the 866.6 keV level.)

680.5 keV level

This level was introduced by Baskova *et al.* The $9/2^-$ spin assignment was made on the basis of angular distribution measurements and supported by the systematics of the $9/2^-$ levels in odd Cd isotopes. According to Baskova *et al.*, two transitions depopulate the level with energies of 435.06 and 284.28 keV. The former would be an M2 transition to the $5/2^+_1$ state. It is very unprobable, especially with a branching ratio of 20% reported in Ref. 1. The statement of Baskova *et al.*, which said that $9/2^-_1 \rightarrow 5/2^+_1$ transition also occurs in ^{113}Cd is incorrect as well. The 322.35 keV transition, which is claimed to be M2, has higher energy than the energy difference of the $9/2^-_1$ and $5/2^+_1$ levels (see also Table II). We place the 435.06 keV transition between the $7/2^-_1$ and $11/2^-_1$ levels. We suggest $2^+_1 \otimes h_{11/2}$ configuration for the 680.5 keV state.

700, 855.6, 1020.7, and 1130.4 keV levels

These levels have been populated by Galperin *et al.*[16] and Singh *et al.*[17] in CELI but not by other investigators, including Baskova *et al.*[1] Blachot and Haas[2] declined to adopt the 700, 1020.7, and 1130.4 keV states since they "could be contaminants because (Galperin *et al.* and Singh *et al.*) used natural Cd". This argument is incorrect. Careful reading of Ref. 16 reveals that Galperin *et al.* used a cadmium target enriched to ~94% in ^{111}Cd. This level of enrichment is estimated by considering the reported abundances of $^{110,112-114}$Cd in the sample[16] and the natural isotopic composition of cadmium.

The interpretation of these levels is difficult. No corresponding states in neighboring Cd-isotopes are found (see section IV.). It is very hard to understand why they were not populated in the (n,γ) and (n,n'γ) experiments[1]. We note that in the case of these levels there is another state within the $E_l \pm 0.01 E_l$

energy interval which was fed in (n,γ), (n,n'γ), and (with the exception of the 1130.4 keV one) in (d,p) reactions and which has a spin S $|S-S_l| \leq 2$. (E_l and S_l are the level energy and spin, respectively.) This "phenomenon" may be fortuitous but it probably has a physical ground. The unusual features of these levels require their further study.

704.6, 1150.7, 1325.9, and 1662 keV levels

These four levels are in close connection with each other and are isolated from the others. Three of them are introduced by us, while the 1325.9 keV level was identified by Baskova *et al.* This level was populated by the strongest primary transition in their (n,γ) experiment. In spite of the strong feeding, Baskova *et al.* had problems to find the depopulating transitions. They stated that the level is depopulated by the 1325.93, 984.5, and 704.66 keV transitions. A simple calculation shows that these three transitions depopulate three different levels. Baskova *et al.* assigned the 984.5 and 704.66 keV transitions to the 1325.9 keV level obviously because the 1325.93 keV transition takes only a quarter of the expected level population away and they have not found the missing ~5.5 units γ-intensity.

One can find the correct solution when supposing that the 1325.9 keV, $3/2^+$ state is the photoactivation level reported by Boivin *et al.*[4] and Chertok and Booth[5] at 1330±10 keV, and considering the deduction described in Ref. 3. The sought transition must decay to an unknown level lying around 700 keV. In the 610-640 keV energy region only the 620 keV multiplet members have an intensity more than 5 units. Although both the 620.31 and 621.2 keV transitions are well-placed in the decay scheme, the large uncertainty of their energy and intensity data indicates that the resolution of the multiplet was not fully successful and a third line could contribute. We note that the quoted uncertainty of the 620.31 keV transition is as high as the intensity of the sought transition. Since the masked line has ~621 keV energy, the $7/2^+$ state have to lie at 705±1 keV.

Dropping the supposition that the 1130.4 keV state is the second photoactivation level but following the deduction of Németh and Veres[3] and searching a level which decays to the ground and ~705 keV, $7/2^+$ states we found the 1150.7 keV level with the desired features. Angular distribution data of the 1150.74 and 446.13 keV transitions suggest $5/2^+$ spin. Since the energy of its depopulating transitions are accurately determined, they give precisely the energy of the $7/2^+$ state, that is 704.61(12) keV. Considering that no γ-transition with an energy higher than 100 keV was observed which could depopulate it, the 704.6 keV level must uniquely decay to the 680.5 keV, $9/2^-$ state. The depopulating 24 keV, E1 transition is evidently strongly converted and one can hope to observe it only by conversion electron spectroscopy. We note that a 704.6 keV→620.2 keV transition also comes into account but we rule it out by considering the features of this level group and the fact that the corresponding 530 keV level in ^{113}Cd cannot decay to the $5/2^+_2$ state since the latter lies higher.

Considering the decreasing spin sequence of the members we suppose that a $1/2^+$ level also belongs to the group. Since the 704.6 and 1325.9 keV levels were strongly populated in (d,p) reaction and the careful investigation of the ^{110}Cd(d,p)^{111}Cd spectrum published by Rosner (Fig. 1 of Ref. 19) does not exclude that the 1150.7 keV state was also fed, we search a level observed in (d,p) reaction with L=0 in the 1.5-1.8 MeV energy region. The only candidate is the 1660±10 keV level[19]. The second step was an investigation if this level, similary to the 1325.9 keV one, was populated by a primary γ-transition following n-capture. In Fig. 4 of Ref. 1, where the spectrum of the primary γ-transitions emitted in the ^{110}Cd(n,γ) reaction is shown, one can find a 5314 keV peak which would feed a 1662±2 keV final level. This line was assigned as a single escape peak by Baskova *et al.* However, neither 6336 nor 5825 keV peaks exist in the spectrum which rules out the identification of the 5314 keV line as an escape peak and suggests that it is a "real" primary transition.

The most intense transition which depopulates the 1662±2 keV level is expected to feed the 1150.7 keV one. However, its energy is 511±2 keV, and this line is obviously covered by the intense annihilation (and/or 507.6 keV) peak(s). There are two candidates for ground state transition: *viz.*, the 1660.6 and 1664.2 keV ones. We placed both in the level scheme but one cannot exclude that one of them is a doublet. The decay properties of this level can apparently be clarified only by a coincidence study. For the interpretation of the 704.6 keV, $7/2^+$, 1150.7 keV, $5/2^+$, 1325.9 keV, $3/2^+$, and 1662 keV, $1/2^+$ levels, see section IV.

736 keV level

This level has been observed in (p,p')[22], (d,d')[21], and (γ,γ')[4] reactions. Although the state has $3/2^+$ or $5/2^+$ spin, it remained hidden in the (n,γ) and $(n,n'\gamma)$ experiments.

752.9 keV level

This is the third $5/2^+$ state which is well known from various experiments. Wang *et al.*[7] interpret it as the $5/2^+$ member of the $2^+_1 \otimes g_{7/2}$ quintet. We suggest $[\pi g_{9/2}]^2 \otimes \nu g_{7/2}$ three-quasiparticle configuration. Such a configuration was proposed for the corresponding 708.5 keV (^{113}Cd) and 749.4 keV (^{115}Cd) levels by Niizeki[24] on the basis of the low (~4.6) log *ft* values observed in the β-decay of the relevant Ag isomers. Since the 752.9 keV level is populated in the β-decay of ^{111}Ag^m with log ft = 4.6[9], the extension of the three-quasiparticle interpretation to this state, as well as to the 820.3 keV (^{117}Cd) and 1053.6 keV (^{119}Cd) states, seems to be reasonable.

754.9 keV level

This state has been populated in β-decay experiments[12], Coulomb excitation[14-18], and (^{3}He,2nγ) reaction[7]. In spite of its $3/2^+$ spin, this level has not been observed by Baskova *et al.* According to Wang *et al.*[7], this is the second member of the $2^+_1 \otimes g_{7/2}$ quintet. This interpretation is questionable, since it is doubtful if any antialigned states were observed in (^{3}He,2nγ) reaction, and the level was only very weakly fed in the CEHI experiment[18].

831.3 keV level

This is the first $7/2^-$ level introduced by us. Six transitions from $3/2^-$-$9/2^-$ states feed it. Since the level population derived from the intensity of the 435.06 keV transition is slightly smaller than expected, a second deexciting transition may exist. The most logical is the supposition of the $7/2^- \rightarrow 9/2^-$ transition. Its energy is 150.8 keV which coincides with that of the more intense isomeric transition making the former to be unobservable. We suggest $2^+_1 \otimes h_{11/2}$ configuration.

854.0, 986.4, and 1256.5 keV levels

These levels have been populated by (n,n'γ)[1], (n,γ)[1], (^{3}He,2nγ)[7], and (α,3nγ)[20] reactions, as well as in CEHI experiment[18]. Both Vetter[18] and we confirm the suggested[7] $2^+_1 \otimes g_{7/2}$ configuration.

864.3 keV level

This level has been populated in (^{3}He,2nγ) reaction[7] and in β-decay[12]. In spite of its low spin this level has not not been observed by Baskova *et al.*

Wang *et al.*[7] suggested that the 864.3 keV level is the $3/2^+$ member of the $2^+_1 \otimes d_{3/2}$ multiplet. However, there is strong evidence against this proposal, *viz.*, the energy difference between the experimental and theoretical value (1107 keV) is large, no other members of the multiplet were populated in the (^{3}He,2nγ) experiment, and we do not find corresponding $3/2^+$ level to the 864.3 keV one in the neighboring odd Cd isotopes. Even the proposed $3/2^+$ spin assignment is to be confirmed.

866.6 keV level

The level has been observed in β-decay[12] and CEHI[18], as well as in (d,p), and (d,t) reactions[19]. Besides the known three depopulating transitions, Baskova *et al.* found a fourth one with an energy of 449.81 keV. Direct feeding of the level following n-capture was also observed by them.

This state, similarly to many other ones in ^{111,113}Cd, has a complex structure. In the one hand, we think that this level and the 620.2 keV, $5/2^+$ one form the $2^+_1 \otimes s_{1/2}$ doublet. The strong population of both levels in the CEHI experiment[18] supports this interpretation. The center of gravity of these levels is only 85.6 keV more than the energy of the 2^+_1 state of ^{110}Cd. The inversion within the doublet is caused by the considerable admixture of the $d_{3/2}$ single particle wave function to the $3/2^+$ member. The 866.6 keV state carries one fourth of the $d_{3/2}$ single particle strength. This contribution elevates the $3/2^+$ member of the $2^+_1 \otimes s_{1/2}$ doublet far above the "unperturbed" $5/2^+$ one in ^{111}Cd and causes its rapid lowering after adding neutron pairs, both in the absolute energy scale and relative to the $5/2^+$ member. The inversion vanishes at ^{115}Cd. The doublet degenerate at ^{119}Cd.

We note that neither the 620.2 keV state has a pure $2^+_1 \otimes s_{1/2}$ character. It is populated in the β-decay of ^{111}Ag^m with log *ft* = 4.9[9], which indicates that it contains a significant $[\pi g_{9/2}]^2 \otimes \nu g_{7/2}$ three-quasiparticle amplitude.

967.8, 1339.6, and 1565.2 keV levels

These levels have been strongly populated *via* (^{3}He,2nγ)[7] and (α,3nγ)[20] reactions but, because of their high spin, only weakly in the experiments of Baskova *et al*. We confirm the proposed $2^+_1 \otimes h_{11/2}$ configurations.

1016.8 keV level

This level was introduced by Baskova *et al.* They observed its feeding by primary γ-transition following n-capture and found three depopulating transitions. They determined the a_2 value of the ground state transition to be different from zero and made $3/2^+$ spin assignment. However, the 1016.8 keV level is the only one which could correspond to the 1020±10 keV state observed by Rosner[19] in (d,p) and (d,t) reaction with L=0. Moreover, the decay properties of this level are very similar to those of the 988.4 keV (^{113}Cd) and 962.7 keV (^{115}Cd) ones, its energy fits well that chain, and the (n,n'γ)/(n,γ) intensity ratios of the depopulating transitions are consistent with $1/2^+$ rather than

$3/2^+$ spin. Considering that the a_2=-0.041(8) value[1] does not differ strikingly from zero and this is the only evidence against the $1/2^+$ spin assignment, we are suspect of the angular distribution measurement and suggest $1/2^+$ spin instead of $3/2^+$.

1046.8 keV level

The level was fed first in (^{3}He,2nγ) reaction by Wang *et al.*,[7] who reported two depopulating transitions. Baskova *et al.* also detected the 801.4 and 704.7 keV transitions but they did not place them in the decay scheme. These two transitions were observed by Vetter and Elze[18] in CEHI as well. We identify further deexciting transitions. We confirm the $7/2^+$ spin assignment[7] and the suggested $4^+_1 \otimes s_{1/2}$ configuration[18].

1115.5 keV level

The level has been observed in Coulomb excitation and (^{3}He,2nγ) reaction. Its feeding by primary γ-transition following n-capture was reported by Baskova *et al.* They proposed $3/2^+$ spin in agreement with the literature. The level is suggested to be the lowest-lying member of the $2^+_1 \otimes d_{5/2}$ multiplet[7]. Considering that Wang *et al.* most likely did not populate antialigned states and the experimental and calculated branching ratios are remarkably different, we are suspect of this interpretation.

1118.4 keV level

This level is introduced by us. The numerous populating and depopulating transitions firmly establish the level. The (n,n'γ)/(n,γ) intensity ratio of the 873.06 and 776.29 keV transitions suggest $7/2^+$ spin. According to our calculations, the a_2 and a_4 values of the 873.06 keV transition reported by Baskova *et al.*, are consistent with the $7/2^+$ spin assignment and indicate a multipole mixing ratio of 0.25(5).

1185.7 keV level

This level is introduced by us. Although we find only one certain transition in connection with this level, a number of indirect evidence supports its introduction. In his (d,p) and (d,t) experiments Rosner[19] found a level at 1190±10 keV with L=0. Since the only known state in this energy interval, the 1190.1 keV one, has $3/2^+$ spin, that cannot correspond to the level populated by Rosner. This means that an unknown level with $1/2^+$ spin lies around 1190 keV. The $(n,n'\gamma)/(n,\gamma)$ intensity ratio of the 1185.72 keV transition is consistent with a $1/2^+$ initial level. Similarly, the experimental level population agrees with the calculated one if $1/2^+$ spin is supposed. The level fits the chain dictated by the 883.4 keV (^{113}Cd) and 649.1 keV (^{115}Cd) states which were also fed in (d,p) and (d,t) reactions[19]. These levels decay also to the first $3/2^+$ state by a weak transition. In Fig. 1 of Ref. 1 there is a small peak around 844 keV, which is either the sought transition itself or covers that.

1274.7 keV level

This level was introduced by Wang *et al.*[7] The level energy given by them is somewhat lower than that deduced from the data of Baskova *et al.*, probably because the former authors were not able to well resolve the 931.8 keV doublet. We identify three further depopulating transitions, two of them predicted by the calculations of Wang *et al.*, who suggested $5/2^+$ spin and $2^+_1 \otimes d_{5/2}$ configuration. Finding the a_2 and a_4 values of the 1029.35 and 932.56 keV transitions to be consistent with $5/2^+$ but contradicting to $7/2^+$ spin, we confirm the suggested spin and configuration.

1288.9 keV level

This new level was strongly populated in (n,γ) but not in $(n,n'\gamma)$ reaction. It is surprising, since one can make a certain $7/2^-$ spin assignment by considering its feeding from a $3/2^-$ and depopulation to a $11/2^-$ level. We suggest $4^+_1 \otimes h_{11/2}$ configuration.

1298.5 keV level

The level was introduced by Wang *et al.*[7] The 1054 and 882 keV transitions were also seen by Baskova *et al.*, but they did not placed them in the decay scheme. We do not find the 446 keV (correctly 444.3 keV) and 312 keV transitions predicted by Wang *et al.* Moreover, the angular distribution data do not support their $9/2^+$ spin assignment. We note that the corresponding 1086.6 keV level of ^{119}Cd decays to a $3/2^+$ level which excludes $9/2^+$ spin. The rapid lowering of the corresponding levels (1047.5 keV, ^{113}Cd, 979.8 keV, ^{115}Cd, 863.5 keV, ^{117}Cd) contradict the proposed $2^+_1 \otimes d_{5/2}$ configuration[7]. We suggest $7/2^+$ spin and $2^+_1 \otimes d_{3/2}$ configuration which are in agreement with most of the experimental data.

1321.6 keV level

This level is introduced by us on the basis of indirect evidence. The 1321.59 keV transition is so intense that it must depopulate a level below 1.8 MeV. This means that it must populate one of the 0.0, 245.4, 342.1, 396.2, and 416.7 keV levels. Because of the low $(n,n'\gamma)/(n,\gamma)$ intensity ratio of the 1321.59 keV transition, the level depopulated by it must have 1/2 or 3/2 spin, thus we can exclude the 396.2 keV level as the searched final state. We have not found any evidence which would verify a level with 1321.59 keV+E energy, where E is 245.4, 342.1, or 416.7 keV. However, supposing that the 1321.59 keV transition is a ground state one, we find a second transition (979.5 keV) which connects the 1321.59 keV level with a known one. The experimental level population is consistent with the theoretical one if $1/2^+$ spin is supposed. A further evidence for the existence of the 1321.6 keV level is that the 5649 keV primary γ-transition, which populates the 1325.9 kev level, is a doublet, as one can see in Fig. 4 of Ref 1. The higher energy component, which is the less intense one, may be the primary γ-transition which feeds the 1321.6 keV level. The existence of this level is to be confirmed.

1326.6 keV level

This is the first $5/2^-$ level introduced by us. Three-three deexciting and feeding transitions establish its existence. The level population suggests $5/2^-$ or $7/2^-$ spin, the lack of its decay to the $11/2^-$ state and the systematics prefer $5/2^-$. Our calculations show that the experimental a_2 and a_4 values of the 646.13 keV transition are consistent with the $5/2^-$ spin assignment and the transition is pure E2. We suggest $4^+{}_1 \otimes h_{11/2}$ configuration.

1340.2, 1391.9, and 1472.7 keV levels

These levels were introduced by Baskova *et al.* They observed the primary feeding of these levels following n-capture and found several depopulating transitions. Two of them were incorrectly placed to these levels. The 1094.8 keV transition depopulates the 1511.5 keV level, as the coincidence studies of Wang *et al.*[7] have shown. The 395.83 keV transition cannot connect the 1472.7 keV and 1078.3 keV levels since their energy difference is only 394.4 keV.

Each level have to have $1/2^+$ or $3/2^+$ spin. Baskova *et al.* suggested $3/2^+$ for the 1391.9 and 1472.7 keV levels but did not make a certain assignment for the 1340.3 keV one. There are two transitions with an energy of around 720.0 keV which depopulate the 1340.3 and 1472.7 keV levels. Since Baskova *et al.* were not able to resolve the doublet, one cannot obtain the experimental population of these levels. Considering the possible population values, it is clear that one of them must be $1/2^+$ and the other to be $3/2^+$. The level deexcited by the more intense 720 keV transition is $3/2^+$, the other is $1/2^+$. Since the energy of the $0^+{}_2$ state of ^{110}Cd is 1473.1 keV, the 1472.7 keV level may have $0^+{}_2 \otimes s_{1/2}$ configuration.

The 1391.9 keV level was assigned to be $3/2^+$ on the basis of angular distribution data, although its population is quite low to be $3/2^+$. Supposing that the 771.2 keV transition is a doublet and its higher energy component depopulates the 1391.9 keV level (a part of) the missing intensity is found.

1341.3 keV level

The level was observed by Wang *et al.*[7] in their (^{3}He,2nγ) experiment for the first time. The 999.1 keV transition seen by them was detected by Baskova *et al.* as well but it remained unplaced. We find two other de-exciting transitions. On the basis of the (n,n'γ)/(n,γ) intensity ratios, the level population, and the angular distribution data of the 999.18 keV transition we suggest $5/2^+$ spin. This state may correspond to the 1195.3 keV (^{113}Cd), 1100 keV (^{115}Cd), 1080.1 keV (^{117}Cd), and 1278.6 keV (^{119}Cd) ones and have $2^+_1 \otimes d_{3/2}$ configuration.

1432.4 and 1506.0 keV levels

These levels are introduced by us. The 1036.20 keV peak must be a doublet and only a minor part of the (n,n'γ) intensity can belong to the low spin 1789.5 keV level depopulating line, considering the high (n,n'γ)/(n,γ) intensity ratio. Similarly, the 752.8 keV peak is believed to be a doublet although in this case only a minor part of the intensity belongs to the high spin state deexciting transition. These two lines, together with the 601.16 keV transition, are placed between the 1432.4 keV and low-lying negative parity states. The angular distribution data excludes $7/2^-$ spin assignment but allow $9/2^-$ and $11/2^-$. Since the introduction of this level is based on mainly indirect evidence, its existence is to be confirmed. A similar statement is valid for the 1506.0 keV level which is introduced by knowing only two depopulating transitions. However, they are singlets and their consistent (n,n'γ)/(n,γ) intensity ratios and the calculated realistic level population, which suggest $(9/2)^-$ spin, lend support for the introduction of this level.

These two states most likely do not belong to the $2^+_1 \otimes h_{11/2}$ or $4^+_1 \otimes h_{11/2}$ multiplets since their (relevant) members are identified. They lie too low for $3^-_1 \otimes$single particle configurations or to have $f_{7/2}$ parentage. The remaining meaningful possibilities are $[\pi g_{9/2}]^2 \otimes \nu h_{11/2}$, $2^+_2 \otimes h_{11/2}$ or $0^+_2 \otimes h_{11/2}$ configurations. The available data are not sufficient to draw unambigous conclusions.

1552.0 keV level

The level was first seen by Wang *et al.*[7] Besides the 932 keV transition observed by them we find the predicted 1135 keV but not the 698 keV ones. We can confirm the suggested[7] $9/2^+$ spin and $4^+_1 \otimes g_{7/2}$ configuration.

1683.1 keV level

This level is introduced by us. It may correspond to the 1692 keV one seen in (p,p') reaction[22] with L=3 and the 1690 keV one observed in (d,d') study[21]. If so, $J^\pi=7/2^-$. However, the level decays only to positive parity states which does not support a negative parity assignment. Restricting ourselves to the data of Baskova *et al.*, we suggest 7/2, 9/2 spin.

1691.9 keV level

This level was introduced by Baskova *et al.* However, two transitions, the 1072.27 and 825.64 keV ones, were incorrectly placed to this level. Their $(n,n'\gamma)/(n,\gamma)$ intensity ratios suggest that these transitions deexcite $J\geq7/2$ spin levels. They neither satisfy the criteria for the introduction of new levels described in section III. We find two other transitions which may depopulate the level. Angular distribution data of the 1691.95 keV transition suggest $3/2^+$ spin while the low $(n,n'\gamma)/(n,\gamma)$ intensity ratio, the weak $(n,n'\gamma)$ population, and the lack of direct feeding prefer $1/2^+$. The existence of this level is to be confirmed.

1740.0, 1789.5, and 1842.5 keV levels

These levels were introduced by Baskova *et al.* Each was fed by primary γ-transitions. Baskova *et al.* made $3/2^+$ or 3/2 spin assignments to each one. They placed the 638.91, 811.95, 873.06, and 1169.7 keV transitions incorrectly to these levels. The 3/2 spin assignments are realistic, but in view of the 1740.0 and 1842.5 keV levels the population and $(n,n'\gamma)/(n,\gamma)$ intensity ratio data suggest $1/2^+$ spin, which value is allowed by the reported angular distribution data.

1800.9 and 1971.8 keV levels

These new levels are introduced by us. They correspond to the 1800 and 1970 keV levels seen in (p,p') reaction[22] with L=3 and the 1790 and 1960 keV levels observed in a (d,d') study[21], respectively. The population and intensity ratio data are in agreement with the $7/2^-$ spin assignment deduced from the (p,p') experiment.

1826.7 keV level

This level was observed by Wang *et al.*[7] for the first time. Their suggested $9/2^+$, $11/2^+$ spin is in agreement with the data of Baskova *et al.* According to Wang *et al.*, this is the $9/2^+$ member of the $1/2^+$[411] band. We note that the information concerned to this level is misprinted in Table III of Ref. 7.

1895.0 keV level

This level is introduced by us. Since it decays only to unfavored states, it obviously has unfavored character itself. We suggest $9/2^-$ spin and $4^+_1 \otimes h_{11/2}$ configuration.

1907.4 keV level

The level has been observed in (^{3}He,2nγ)[7] reaction. Besides the 1054 keV transition reported by Wang *et al.*[7], we place the 1490.7 keV one to this level. They suggested $(7/2-11/2)^+$ spin with a preference of $11/2^+$ and $4^+_1 \otimes g_{7/2}$ configuration. The relatively strong population of the level in the (n,n'γ) experiment supports a lower spin value. We do not confirm the proposed configuration and do not suggest certain spin value.

1992.8 keV level

We found transitions deexciting this new level to the first $9/2^-$, $7/2^-$, and $5/2^-$ states. Considering the lack of its decay to the $11/2^-_1$ state and the strong level population, we suggest $5/2^-$ spin and $6^+_1 \otimes h_{11/2}$ configuration.

2006.0 keV level

We introduce this level by finding depopulating transitions to the first

$1/2^+$, $3/2^+$, $5/2^-$, and $7/2^-$ states. It exhibits very similar decay properties and obviously corresponds to the 1194.4 keV (^{113}Cd), 1092.1 keV (^{115}Cd), and 1073.4 keV (^{117}Cd) levels. We make certain $3/2^-$ spin assignment and suggest $4^+_1 \otimes h_{11/2}$ configuration.

2097.3 keV level

This is a new level introduced by us. It is striking that none of the depopulating transitions feed the first $1/2^+$-$7/2^+$ states. On the basis of the level population and (n,n'γ)/(n,γ) intensity ratios we suggest $5/2^+$, $7/2^+$ spin with a preference of the latter.

2325.5 keV level

This level was introduced by Baskova *et al.* They reported its feeding by primary γ-transition following n-capture. It is questionable whether the 1135.16 keV transition deexcite this level, since one may also place that to the 1552.1 keV level. The experimental level population is far below the calculated one. We feel that the existence of this level is to be confirmed.

Levels above 2.3 MeV

We found 16 new levels in the 2.33-3.2 MeV energy region. Most of them were not or only weakly populated in (n,n'γ) reaction. In five cases we managed to identify the corresponding primary transitions. Since in this energy region the intensity and energy data have high uncertainties, we used strickter criteria. We introduced a new level when at least four depopulating transitions were found. In the five cases when primary transitions were connected with secondary ones we required two depopulating transitions to low-lying states to introduce a new level.

All the 16 levels have 1/2-7/2 spin, most of them probably 1/2 or 3/2 with positive parity. In the case of the 2588.4 and 2710.3 keV levels it is possible to make certain $3/2^+$ and $3/2^-$ assignments, respectively.

2. ^{113}Cd

The level structure of ^{113}Cd has been investigated by β-decay experiments[24-28], CELI[14,17,29], CEHI[30], (d,p)[19,31] (d,t)[19] (d,d')[21] and (p,p')[22] reactions. Benczer-Koller *et al.*[23] reported g-factors of the lowest lying levels. The results for ^{113}Cd are summarized in Table II. We discuss below in details the levels which have special importance or for which there is a considerable amount of new information. The configuration mixing, similarly to ^{111}Cd, is very strong. Besides the proposed dominant configurations, other ones can significantly contribute the total wave function of the individual states.

0.0, 263.3, 298.6, 316.2, and 458.5 keV levels

These are the first $1/2^+$, $11/2^-$, $3/2^+$, $5/2^+$, and $7/2^+$ levels, respectively, which are well-known from various nuclear reactions as single particle states. There is clear evidence, however, for configuration mixing, just as in the case of ^{111}Cd. The strongest of them are, again, the fragmentation of the single particle strengths in (d,p) reaction and the "anomalous" magnetic moment of the ground state.

522.2 and 638.0 keV levels

These are the first $7/2^-$ and $9/2^-$ levels, respectively, which have been observed in β-decay experiment[28]. They correspond to the 831.3 keV (^{111}Cd), 393.9 keV (^{115}Cd), 293.5 keV (^{117}Cd), and 228.1 keV (^{119}Cd) and 680.5 keV (^{111}Cd), 417.2 keV (^{115}Cd), 278.4 keV (^{117}Cd), and 213.8 keV (^{119}Cd) levels, respectively. Since Baskova *et al.* determined the energy of the 206 and 259 keV transitions more accurately than Matumoto *et al.*[28], it is possible to give more precisely the isomer state energy: 316.21 keV+205.86 keV−258.72 keV=263.35 keV. This value is more than 0.2 keV lower than that reported by Matumoto *et al.*[28] We suggest $2^+_1 \otimes h_{11/2}$ configuration for both states.

530 keV level

This is the second $7/2^+$ level which has been observed in (d,p) reaction by Rosner[19] and Goldman *et al.*[31] It corresponds to the 704.6 keV (^{111}Cd) and 389 keV (^{115}Cd) levels. Since no depopulating γ-transition was found, this level is expected to decay exclusively to the $7/2^-_1$ state with a low energy, strongly converted transition, just as the 704.6 keV level of ^{111}Cd decays exclusively to the $9/2^-_1$ state. Another remarkable feature of this state is that it carries more than a half of the $g_{7/2}$ single particle strength, more than the 458.6 keV "single particle state".

583.9 and 680.6 keV levels

These levels are also well-known from the literature. We suggest $2^+_1 \otimes s_{1/2}$ configuration for both. The center of gravity of these two states is only 14.6 keV above the 2^+_1 level of ^{112}Cd, which lies at 617.6 keV. The inversion, caused by the admixture of $d_{3/2}$ single particle configuration to the 680.6 keV level, exist yet, although the elevation of the $3/2^+$ member is considerably smaller comparing to ^{111}Cd.

The 583.9 keV state is also more pure than the corresponding 620.2 keV level in ^{111}Cd. The latter was fed with a log *ft* value of 4.9 following the β-decay of ^{111}Ag^m, while the equivalent value for the 583.9 keV state[24] is 5.34. This is an indication of the diminishing of the $[\pi g_{9/2}]^2 \otimes \nu g_{7/2}$ three-quasiparticle configuration admixture. This trend continues after adding a further neutron pair. No level corresponding to the 620.2 keV and 583.9 keV ones has been observed[24,26] in the decay of ^{115}Ag^m. We interpret this as being due to the cancellation of the admixture of the three-quasiparticle configuration, since the neutron shell is over half full.

708.5 keV level

This state has been fed in β-decay[24–28], CEHI[30], and CELI[29] experiments. The latter statement is based on the fact that Andreev *et al.*[29] reported a 391 keV transition, which must be the same as the 392.36 keV one observed by Baskova *et al.*, and that is the most intense depopulating transition of this level. Niizeki[24] suggested $[\pi g_{9/2}]^2 \otimes \nu g_{7/2}$ three-quasiparticle configuration on the basis of the low (4.53) log *ft* value observed in the β-decay of $^{113}Ag^{m}$.

760 keV level

This level has been seen in (d,p) reaction by Goldman *et al.*[31] with L=0, thus it have to have $1/2^{+}$ spin. However, it was not populated in the (n,n'γ) study of Baskova *et al.* It corresponds to the 803 keV level of ^{115}Cd and carries 20% of the $s_{1/2}$ single particle strength[31].

816.7 keV level

This is a new level introduced by us. Its existence is confirmed by Kröll and Elze[30]. Angular distribution data of the 500.47 keV transition suggest $7/2^{+}$ spin assignment. Since its collectivity and its decay properties are similar to those of the 854.0 keV level (^{111}Cd), we propose $2^{+}_{1} \otimes g_{7/2}$ configuration.

855.0 keV level

This is the first $5/2^{-}$ level, which is the lowest-lying member of the $4^{+}_{1} \otimes h_{11/2}$ nonet. Its strong suppression is remarkable. We note that Matumoto *et al.*[28] incorrectly placed a 539±1 keV transition to this level. Baskova *et al.* determined more accurately its energy to be 539.39 keV which exceeds by 0.58 keV the energy difference of the 855.0 and 316.2 keV levels. This means that the 855.0 keV level decays only to negative parity ones. We placed the 539.39 keV transition to the 1542.3 keV level.

869.7, 1209.3, and 1423.4 keV levels

These new levels have $15/2^{-}$, $13/2^{-}$, and $11/2^{-}$ spins, respectively, and correspond to the 967.8, 1339.6, and 1565.5 keV levels of ^{111}Cd, respectively. We suggest $2^{+}_{1} \otimes h_{11/2}$ configuration for each.

878.5 keV level

This level is introduced by us. Andreev *et al.*[29] observed a 878.2±0.2 keV peak in their CELI study. Kröll and Elze[30] have also seen the ground state transition. The level shows decay properties very similar to those of the 776.6 keV (^{115}Cd), 665.2 keV (^{117}Cd), and 655.5 keV (^{119}Cd) ones but, unlike those, has not been populated in (d,p) reaction. See also the discussion of the 897.5 keV level.

883.6 keV level

This level must be the same as was observed at 880 keV in (d,p) reaction by Goldman *et al.*[31] with L=0. Its consequence is a certain $1/2^+$ spin assignment. Primary population of this level following n-capture was reported by Baskova *et al.* It corresponds to the 1185.7 keV (^{111}Cd) and 649.1 keV (^{115}Cd) states. On the basis of the rapid lowering of the corresponding levels for increasing neutron numbers, we suggest $2^+_1 \otimes d_{3/2}$ configuration. We note that the coincidence studies of Matumoto *et al.*[27,28] and Hnatowich *et al.*[25] showed that the 583.9 keV line is a doublet. The more intense part has no coincidence connections and evidently is the ground state transition from the second $5/2^+$ level. The less intense part is in coincidence with the 298.6 keV transition and is placed to the 883.6 keV level.

897.5 keV level

This level is introduced by us. Its existence has been confirmed by Kröll and Elze[30]. The level was considerably populated in (d,p) reaction, similarly to the 776.6 keV (^{115}Cd) and 665.2 keV (^{117}Cd) ones, but has decay properties different from those of the latter ones. Because of the controversial nuclear properties, it is hard to decide if the 878.5 keV or the 897.5 keV level corresponds to the aforementioned states.

959.0 keV level

This level was incorrectly introduced by Baskova *et al.* We placed the transitions attributed to deexcite this level between other states.

988.4 keV level

This level has been seen in β-decay[25,27,28] and in (d,p)[19,31] and (d,t)[31] reactions with L=0. Direct feeding of the level following n-capture was reported by Baskova *et al.* Undoubted $1/2^+$ spin assignment can be made. It corresponds to the 1016.8 and 962.7 keV levels in ^{111}Cd and ^{115}Cd, respectively.

1007.1 keV level

The level has been observed in the β-decay of $^{113}Ag^m$ by Brüchle[26] and by Niizeki[24]. Baskova *et al.* incorrectly placed the 1007.50 keV transition to this level and deduced $5/2^+$ spin. The angular distribution data of the 691.00 keV transition suggest $7/2^+$ spin. This state corresponds to the 1118.4 keV (^{111}Cd), 1063.2 keV (^{115}Cd), 1277.0 keV (^{117}Cd), and 1538.7 keV (^{119}Cd) ones. On the basis of the evolution of the corresponding levels we propose $2^+_1 \otimes d_{5/2}$ configuration.

1033.8 keV level

This new level has decay properties similar to those of the 1115.6 keV, $3/2^+$ level of ^{111}Cd. The angular distribution data of the 1033.8 keV transition confirm the $3/2^+$ spin assignment.

1037.4 keV level

This is a new level introduced by us. Its existence is confirmed by Kröll and Elze[30]. It corresponds to the 1046.8 keV, $7/2^+$ level of ^{111}Cd. Angular distribution data of the 721.22 keV transition confirm the $7/2^+$ spin assignment. We propose $4^+_1 \otimes s_{1/2}$ configuration.

1047.5 keV level

This level has been seen following the β-decay of $^{113}Ag^m$ by Niizeki[24] and by Brüchle[26]. We suggest $7/2^+$ spin, in accord with Brüchle[26] and Baskova *et al.*[1], and $2^+_1 \otimes d_{3/2}$ configuration.

1050.8 keV level

This level is introduced by us. $7/2^-$, $9/2^-$, $11/2^-$ spin assignments are possible. The angular distribution data disfavor $9/2^-$ while the strong population suggests $7/2^-$ rather than $11/2^-$ spin. The level may correspond to the

1288.9 and 872 keV levels in ^{111}Cd and ^{115}Cd, respectively. We suggest $4^+_1 \otimes h_{11/2}$ configuration.

1177.2 and 1313.7 keV levels

These levels were introduced by Kröll and Elze[30]. Their remarkable population in the CEHI experiment indicates that they have collective nature. Since states of $d_{3/2}$ and $d_{5/2}$ parentage have not been populated in CEHI experiments[18,30], the 1177.2 and 1313.7 keV levels must have $g_{7/2}$ parentage. They may carry dominant amplitudes of $2^+_1 \otimes g_{7/2}$ configuration. The 1313.7 keV level corresponds to the 1511.5 keV one (^{111}Cd). The 1177.2 keV state may be the pair of the 1391.9 keV one (^{111}Cd). The facts that these levels lie relatively high, both in the absolute energy scale and relative to the aligned members of the $2^+_1 \otimes g_{7/2}$ quintet, they do not decay dominantly to the $g_{7/2}$ single particle state, and the energy difference between the corresponding pairs is ≈200 keV suggest significant admixture of other (most likely of $d_{3/2}$ parentage) configuration.

1194.4 keV level

The level has been observed in β-decay experiments[24–27]. Baskova *et al.* reported its direct feeding following n-capture and suggested 3/2 spin. The level decays both to negative and to positive parity states, including the ground state, thus it is a photoactivation level. Our calculations show that the 339.3 keV transition is M1+E2. Its consequence is certain $3/2^-$ spin assignment. The level corresponds to the 2006.0 keV (^{111}Cd), 1092.1 keV (^{115}Cd), and 1073.4 keV (^{117}Cd) ones. We suggest $4^+_1 \otimes h_{11/2}$ configuration.

1195.3 keV level

The level has been observed in β-decay by Brüchle[26] and in (d,p) and (d,t) reactions by Rosner[19] and Goldman *et al.*[31] with L=2. Considering the small log *ft* value and the $7/2^+$ parent, we make a certain $5/2^+$ spin assignment. The level, which has not been populated in the experiments of Baskova *et al*, probably corresponds to the 1100 keV (^{115}Cd), 1080.1 keV (^{117}Cd), and 1278.6 keV (^{119}Cd) ones. We suggest $2^+_1 \otimes d_{3/2}$ configuration.

1321.9 keV level

This new level may correspond to the 1320 keV one observed in (d,p) reaction by Goldman *et al.*[31] $7/2^-$-$11/2^-$ spins are possible, the branching ratios and the strong population suggest the lowest possible value, $7/2^-$.

1390.5 keV and 1405.8 keV levels

These levels are introduced by us. Both decay only to $1/2^+$ and $3/2^+$ states and obviously have $1/2^+$ or $3/2^+$ spin themselves. The former may be the 1390 keV level seen in (d,p) reaction by Goldman *et al.*[31], the latter corresponds to the 1472.7 keV state in ^{111}Cd.

1407.4 keV level

This new level has decay characteristics similar to those of the 1552.0 keV level in ^{111}Cd. On the basis of the similarities we introduce the level (with question mark), propose $9/2^+$ spin assignment and $4^+_1 \otimes g_{7/2}$ configuration.

1430 keV level

This level was considerably populated in (d,p) reaction[30] with L=2 but not in the (n,n'γ) experiment of Baskova *et al.*

1479.2 keV level

This is the highest-lying level identified by Baskova *et al.* Its feeding by primary γ-transition following n-capture was also reported by them. The level has been also observed in the β-decay studies of Matumoto *et al.*[27,28] They suggested $1/2^-$, $3/2^\pm$ spin. If the level is the same as the 1490$\pm$10 keV one observed by Goldman *et al.*[30] with L=2, than one can make a certain $3/2^+$ spin assignment. If not, $1/2^-$ or $3/2^-$ assignments are also possible, considering that the level decays to both positive and negative parity states. It is the second photoactivation level, independently of its spin.

1542.3 keV level

This is a new level introduced by us. The 539.39 keV transition must be the same as the 539±1 keV one observed by Matumoto *et al.*[27,28] in their β-decay experiment. They placed this transition to the 1479.2 keV level which is energetically correct. However, the intensity ratio of the 539.39 and 1180.70 keV transitions is ~0.2 in their study[28] while ~1 is in the (n,n'γ) experiment. We solved the contradiction by placing the 539.39 keV transition to the 1542.3 keV level. Having $1/2^+$ (or $3/2^+$) spin, its population following the β-decay of ^{113}Ag, which has $1/2^-$ spin, is possible. Since the 539 keV transition was the weakest one observed by Matumoto *et al.*[28], it is not surprising that the 658.66 keV transition, obviously as weak as the 539 keV one, has not been found by them. We conclude that this level has been fed in the β-decay studies but Matumoto *et al.*[27,28] did not realize that. Besides the β-decay and (n,n'γ) experiments, the level has been populated in (d,p) reaction[31] as well.

1575.3 keV level

This new level corresponds to the 1580 keV state observed by Goldman *et al.*[31] in (d,p) reaction with L=3(?). One cannot exclude that further de-exciting transitions exist besides the identified ones. Possible transitions to the first $5/2^-$ and $3/2^-$ states, however, are covered in the spectrum by intense peaks. We propose $7/2^-$ spin on the basis of the population and branching ratio data, confirming the angular momentum transfer value of Goldman *et al.*[31]

1607.2, 1675.1, and 1798.8 keV levels

These levels are introduced by us. Each is depopulated by at least four transitions and corresponds to a level seen in (d,p) reaction by Goldman *et al.*[31] We suggest $5/2^+$, $3/2^+$, and $(1/2-5/2)^+$ spins, respectively, in agreement with the assignments proposed by Goldman *et al.*

1745.9 keV level

This new level decays to the first $1/2^+$, $3/2^-$, $5/2^-$, and $5/2^+$ states, with a high preference of the negative parity ones. This suggest negative parity with a consequence of certain $3/2^-$ spin assignment. We propose $6^+_1 \otimes h_{11/2}$ configuration. This is the third photoactivation level.

1778.7 and 2093.9 keV levels

These levels are introduced by us. Considering their energies and decay properties, they can be the $9/2^-$ and $7/2^-$ members of the $4^+_1 \otimes h_{11/2}$ nonet. Both decay to the $11/2^-_1$ state and to the corresponding J+2 member of the $2^+_1 \otimes h_{11/2}$ quintet, in contrary to other members of the aforementioned multiplets which decay also to J+1 states by considerable branching ratios.

Further levels above 1.8 MeV

We introduce nine new levels in the 1.8-2.8 MeV energy region. Most of them are certainly or very probably correspond to a state observed in (d,p) or (p,p') reaction. This fact made certain spin-parity assignments possible in three cases. The 2173.5 and 2319.5 keV levels decay both to negative and positive parity states, including the ground state. This means that these are the fourth and fifth photoactivation levels, respectively. They carry a part of the $p_{3/2}$ single particle strength[31]. This indicates that roughly 2 MeV excitation energy is enough to lift the odd neutron to the next shell.

Koike found in his (p,p') experiment[22] three levels with L=3 between 1.6 and 2.0 MeV both in ^{111}Cd and in ^{113}Cd. We note that the lowest-lying ones have not been populated in the (n,n'γ) and (n,γ) experiments, while we could identify the middle ones in both nuclides. We find the highest-lying member only in ^{111}Cd, the corresponding pair of the 1986 keV state is to be identified.

3. Binding energies of the last neutrons

In Ref. 8 Baskova *et al.* reported the binding energy of the last neutron in ^{111}Cd. Their value, 6975.5(5) keV, is simply the energy of the ground state feeding primary γ-transition without recoil correction. In order to get a more precise value we sum the energies of the primary transitions and the respective final level energies up and calculate their weighted average. The same procedure is performed for ^{113}Cd as well. After recoil correction we obtain 6975.9(2) and 6542.0(2) keV for ^{111}Cd and ^{113}Cd, respectively. The new binding energies supersede the adjusted values of Wapstra and Audi[32] which are 6975.2(24) and 6540.2(5) keV, respectively.

4. B(E2) values of the $7/2^-{}_1 \rightarrow 11/2^-{}_1$ transitions in odd Cd isotopes

The shape of the medium-weight odd Cd isotopes has not been clarified. Vetter[18] showed that the small negative magnetic moment of the $1/2^+$ ground state of ^{111}Cd can be evidently interpreted by supposing an oblate deformation. A further possibility is the triaxiality. The triaxial-rotor-plus-particle model[33] has been successfully employed in the A≈135 and A≈190 regions. Ohya *et al.*[34] investigated the B(E2) values of the $7/2^-{}_1 \rightarrow 11/2^-{}_1$ transitions in $^{113-119}$Cd and compared them with the predictions of the triaxial-rotor-plus-particle model[33]. They found a parabolic behavior rather than slowly increasing values forecasted by the model.

We investigate if the parabolic "distribution" is valid for lighter Cd isotopes. The $7/2^-{}_1$ levels are identified at 831.8 keV at ^{111}Cd and at 1848 keV in ^{109}Cd. Since the energy of the $7/2^-{}_1 \rightarrow 11/2^-{}_1$ transition in ^{109}Cd is 1387 keV, the corresponding B(E2) value must be in order of 10^{-3} e^2b^2 which agrees with the prediction of the empirical "parabolic rule". We calculate analytically the parabola which fits the B(E2, $7/2^-{}_1 \rightarrow 11/2^-{}_1$) values of ^{109,117,119}Cd. We have three reasons why the B(E2) value of the 1387 keV transition has been chosen to be a fix point although the half-life of the 1848 keV level is not known: (a) since it is small, the calculation is not sensitive to its exact value. The actual value is obtained from the Weisskopf-estimated half-life and the supposition of an enhancement of 20, in agreement with the equivalent values in $^{113-119}$Cd. Nevertheless, no reasonable enhancement value would result in considerable change in the parameters of the parabola. (b) the B(E2) values of the 258.7 keV (^{113}Cd) and 212.8 keV (^{115}Cd) transitions reported by Ohya *et al.*[34] are in conflict with their own (original) half-life data. (c) interpolation is always better than extrapolation.

The results are shown numerically in Table III and graphically in Fig. 1. We obtain values in good agreement with the recalculated B(E2) of the 258.7 and 212.8 keV transitions. The parabolic "rule" predicts B(E2)=0.092(8) e^2b^2 for the 435.06 keV transition which corresponds to a partial half-life of 42(4) ps. This implies that the enhancement is around 21, in excellent agreement with the equivalent values which lends support to this empirical "rule". Unfortunately, one cannot calculate the total half-life of the 831.3 keV level, since the $7/2^-_1 \rightarrow 9/2^-_1$ transition is covered in the spectra of Baskova *et al.*, and the branching ratios are not known. We note that the calculated axis of the parabola is the line x=115 within error limits. This means that the evolution of the B(E2, $7/2^-_1 \rightarrow 11/2^-_1$) values is unbroken which justifies nuclear physical background behind the parabolic "rule". A possibility is that the B(E2,$7/2^-_1 \rightarrow 11/2^-_1$) values are related to the deformation, which is obviously the largest when the valence shell is half full.

V. Interpretation and level systematics

The low-spin levels of the medium-weight odd Cd-isotopes have not been extensively studied theoretically. The only detailed calculation is of Wang *et* *al.*[7] for ^{111}Cd in the framework of the symmetric particle-plus-rotor model. They supposed a deformation of δ=0.10 and predicted multiplets created by the Coriolis interaction when single particle states are coupled to R=2 or R=4 core spins. All states observed in their (^{3}He,2nγ) experiment were interpreted accordingly.

This rotational interpretation seems to be valid for a (small) part of the observed levels. The $2^+_1\otimes s_{1/2}$ doublet, the $7/2^+$ member of the $4^+_1\otimes s_{1/2}$ doublet, the aligned members of the $2^+_1\otimes g_{7/2}$ quintet, and the $9/2^+$ member of the $4^+_1\otimes g_{7/2}$ nonet were observed in CEHI experiment, confirming their collective nature. The aligned members of the $2^+_1\otimes h_{11/2}$ and $4^+_1\otimes h_{11/2}$ multiplets are also reasonably reproduced by the calculations of Wang *et al.* The strong configuration mixing observed in various reactions confirms that the Coriolis-interaction plays a dominant role in the formation of the excited states. On the other hand, the interpretation of some levels given by Wang *et al.*[7] is incorrect, as we have shown above. We are in doubt that *any* antialigned states were populated in the (^{3}He,2nγ)[7] (as well as in the (α,3nγ)[20] and CEHI[18]) experiments.

The status of the predicted rotational multiplets[7] is considerably different. All aligned members of the multiplets of $g_{7/2}$ and $h_{11/2}$ parentage have been observed[7,18,20] (R≤4), with the remarkable exception of the $7/2^+$ member of the $4^+_1\otimes g_{7/2}$ nonet. On the contrary, only one or two probable members of the $2^+_1\otimes d_{3/2}$ and $2^+_1\otimes d_{5/2}$ multiplets, and none of the $4^+_1\otimes d_{3/2}$ and $4^+_1\otimes d_{5/2}$ multiplets have been seen[7]. No levels of $d_{3/2}$ and $d_{5/2}$ parentage were observed in CEHI[18], indicating the lack of the occurance of such collective states. These facts designate the validity limits of the rotational interpretation and indicate an intimate connection between the occupation of the various subshells and the collectivity of states of different parentage. While the aligned levels of multiplets of $g_{7/2}$ and $h_{11/2}$ parentage fit the rotational picture, this model is apparently not valid for antialigned states and for $d_{3/2}$ and $d_{5/2}$ parentage.

^{113}Cd shows much similarities to ^{111}Cd. Levels of $s_{1/2}$ parentage up to $7/2^+$ spin as well as aligned members of the $2^+_1 \otimes g_{7/2}$ quintet were observed in CEHI experiment[30]. Their interpretation by the symmetric particle-plus-rotor model may be realistic. Five levels with unknown configuration and without identified corresponding pairs in ^{111}Cd were also populated in that CEHI study in the 0.8-1.6 MeV energy range, indicating the presence of further collectivity. These states, most probably, have no $d_{3/2}$ or $d_{5/2}$ parentage. This fact verifies as substantial differences among the states of different parentage as in the case of ^{111}Cd.

In the present work we managed to identify a number of low-lying low-spin negative parity levels both in ^{111}Cd and in ^{113}Cd. Lying below 2 MeV, they cannot correspond to coupling of positive parity single particle states with the 3^- core of the even-even core or contain dominant amplitudes for the negative parity single particle states from the N=82-126 shell. Therefore, they must be predominantly unique-parity levels emerging from the coupling of an $h_{11/2}$ neutron to the low-lying positive parity excitations of the core. As such, they form an isolated family.

The theory predicts that both aligned[35] and antialigned[36,37] states are produced by the extreme weak coupling of an $h_{11/2}$ particle and a symmetric rotor core, which form parabolae on the R - (j+R-n) plane[36]. Here R is the core spin, j is the particle angular momentum and n is related to the angle between $\vec{R}$ and $\vec{j}$. Figure 2 shows the identified unique-parity levels of ^{111,113}Cd. It is immediate evident that there are remarkable disagreements. Although the yrast favored (n=0) states are correctly predicted, the n>0 levels on the antialigned side occur much lower in energy than given by the calculations and more compressed as well. The majority of the unique-parity states decay also to positive parity ones. This fact shows that these levels are not pure as predicted[37]. Our conclusions are in full agreement with those of Casten *et al.*[38], who found similar "anomalous" behavior of antialigned unique-parity states of ^{109}Pd which has 63 neutrons, just as ^{111}Cd. We note that the set of antialigned unique-parity states identified by Casten *et al.*[38] is equivalent with those found by us in ^{111,113}Cd. Due to light ion studies[7,20], yet, a dozen of aligned unique-parity levels up to $27/2^-$ spin have also been known in ^{111}Cd. These two subsets form, as we know, the largest set of unique-parity states with nearly equal participation of both alignment types.

The unique-parity states of ^{113}Cd exhibit much similarities to those of ^{111}Cd. There are, however, clear differences. One of them is that they are even more compressed than those in ^{111}Cd. The electromagnetic properties are also different. While these levels decay dominantly by E2 transitions in ^{111}Cd, keeping the favored and unfavored states separate, the corresponding states in ^{113}Cd are deexcited by M1+E2 transitions with a fairly constant multipole mixing ratio of −0.25. There is another spectacular evidence for the failure of the rotational interpretation and for the complexity of the structure of these isotopes. As one can see from Fig. 3, a number of levels in both nuclides fit straight lines in the energy-spin plane, indicating severe distortion of the rotational pattern.

The most exciting subset in the level scheme of ^{111}Cd is a group of isolated positive-parity states with decreasing spin sequence, formed by the 704.6, 1150.7, 1325.9, and 1662 keV levels. These levels have been populated in (d,p) reaction[19] and two of them in (γ,γ') reaction[4–6]. No transitions feeding these states were found except primary and intraband transitions. The 1150.7 and 1325.9 keV levels decay by enhanced transitions to the 704.6 keV one and by strongly hindered ground state transitions. The $\Delta J=1$ transitions have dominant E2 contributions. The 704.6 keV "bandhead" must be depopulated by a 24 keV E1 transition to the $9/2^{-}_{1}$ level. Although the decay properties of the 1662 keV level are not sufficiently known, there is evidence for the similarity to the lower-lying members. These levels fulfil the criteria to be intruder states: (i) rotational band-like structure (although the decreasing spin sequence is surprising), (ii) enhanced intraband E2 transitions, (iii) retarded interband transitions, (iv) strong excitation in (d,p) but weak feeding in (d,t) reaction.

The integral (γ,γ') cross section data[4-6,39-43] (see Table IV.) give a hope that one can deduce the half-lives of the 1150.7 and 1325.9 keV states which are identified as photoactivation levels. We managed to clarify most of the problems concerned to the photoactivation data. It is clear that the contradiction among the "old" and "new" results from linear accelerator (linac) based experiments is not so serious as felt by Anderson *et al.*[6]

Since there are two activation levels not too far from each other, the problem is the interpretation of the cross section data. Anderson *et al.*[6] obviously populated both activation levels. Thus the integral cross section value reported by them for the 1190±100 keV level is an upper limit. The contribution of the 1325.9 keV level to the feeding of the metastable state depends on the cross section and γ-flux ratios. It is not so easy to estimate reliably these quantities. Figure 6 of Ref. 44 suggests that the 1151 keV/1326 keV γ-flux ratio $(I^{\gamma}_{1151}/I^{\gamma}_{1326})$ was dependent on the endpoint energy but was roughly 10-100 in the experiment of Anderson *et al.*[6]

When estimating the cross section ratio one faces the only contradiction remained among the linac data. A simple calculation shows that $\sigma_{1151}/\sigma_{1326}= 0.5\times T^{1326}_{1/2}/T^{1151}_{1/2}$, where the σ are the integral cross sections and the $T_{1/2}$ are the level half-lives. The common sense, Weisskopf-estimations, and the results of Anderson *et al.*[6], suggest that $\sigma_{1151}/\sigma_{1326}$ and $T^{1151}_{1/2}/T^{1326}_{1/2}$ are in order of 1. However, Boivin *et al.*[4], obtained a cross section ratio of $\approx 10^{-3}$

while Chertok and Booth[5] have not observed the 1150.7 keV state at all.

Turning to the cross section data obtained by ^{60}Co sources[39-43], one can see that, with one exception, they are consistent with 13×10^{-26} cm^{2}eV. (We note that we do not take into account cross section values which were got by the supposition of the disproved "nonresonant" process.) Of course, those results are based on the supposition of a single activation level around 1330 keV. The unanimity is surprising, considering that the flux ratio of the Compton-scattered photons at 1151 and 1326 keV may vary from setup to setup, and that is an indirect evidence for a cross section ratio of ≈1.

The "decomposition" of the 13×10^{-26} cm^{2}eV integral cross section value is dependent again upon $\sigma_{1151}/\sigma_{1326}$. Surprisingly, the simplest guesses on the cross section and γ-flux ratios lead to a good agreement with the greatest part of the existing experimental data. If one supposes that $\sigma_{1151}/\sigma_{1326}=1$ and $I^{\gamma}_{1151}/I^{\gamma}_{1326}=2$ (remember that 1150.7 keV photons stem from the Compton-scattering of both the 1174 and the 1332 keV ^{60}Co transitions while 1325.9 photons only from the latter one), obtains $\sigma_{1151}=\sigma_{1326}\approx8\times10^{-26}$ cm^{2}eV in agreement with σ_{1151} of Anderson *et al.*[6] and σ_{1326} of Boivin *et al.*[4] The only unclear point is the disagreement of the two experimental σ_{1151}. The corresponding half-lives are 4.6 and 2.3 ps for the 1150.7 and the 1325.9 keV levels, respectively. Considering the simplicity of the estimation, the uncertainty of these values is a factor of 2. These half-lives yield transition strengths of 10^{-3} W.u. (1325.9 keV, M1 interband transition), 60 W.u. (621.3 keV, E2 intraband transition), and 0.16 W.u. (1150.7 keV, E2 interband transition). The interband transitions are hindered, while the 621.3 keV intraband transition in strongly enhanced, as expected. The unknown multipole mixing ratio prevents us to estimate the strength of the 446.1 keV transition.

The isolation of these levels as well as the fulfilled four criteria suggest a dominant intruder configuration. The decreasing spin sequence and the nearly constant level spacing are unusual features comparing with those of known intruder bands. The existence of the interband transitions, the slight upshifting of the 1150.7 keV level, and the relatively high branching ratio of its ground state transition, however, imply the admixture of some "normal" configuration, especially in the case of the $5/2^+$ member. We could not clarify if such a set of states exists in ^{113}Cd. Nevertheless, the fact that the 704.6 keV, $7/2^+$ bandhead has a corresponding pair in ^{113}Cd at 530 keV suggests a positive answer.

The shape of the medium-weight odd Cd-isotopes is still a persisting problem. Calculations of Meyer *et al.*[50] indicated that the features of the decoupled quasirotational bands built on the $h_{11/2}$ and $g_{7/2}$ single particle states in ^{111}Cd can be understood only if a prolate shape is supposed. Although their deformation energy curve (*versus* quadrupole moment) had two minima in ^{110}Cd, one in the oblate and one in the prolate side, they have not found evidence for shape coexistence at low energies. Vetter[18] suggested an oblate shape for the ground state by analyzing its magnetic moment. Although our results for the B(E2, $7/2^-_1 \rightarrow 11/2^-_1$) values do not verify a triaxial shape, they are not unambigous evidence against triaxiality. We note that recently Paul *et al.*[51] concluded that electromagnetic properties of N=75 isotones provide evidence for their triaxial shape.

Considering the available data for ^{111}Cd, it is hard to believe that this nuclide can be described without the supposition of shape coexistence. Among others, the occurance of an intruder-like band, which we discuss above in details, is an evidence for that. ^{113}Cd is expected to be similar to ^{111}Cd, with the remark, that the results presented above indicate a significant evolution of the odd Cd isotopes.

The systematics of the low-lying levels in $^{111-119}$Cd are shown in Figs. 4 and 5. The level schemes are based on this work (^{111,113}Cd), Refs. 19, 24, 26, 45, 46 (^{115}Cd), Refs. 19, 47, 48 (^{117}Cd), and Ref. 49 (^{119}Cd). Most of the spin-parity assignments reported in the aforementioned papers turned to be correct. We change the suggested spins only in two cases. We propose $5/2^+$ spin and $2^+_1 \otimes s_{1/2}$ configuration for the 442.6 keV level of ^{117}Cd. This state exhibits decay properties analogous to those of the 620.2 keV (^{111}Cd) and 583.9 keV (^{113}Cd) ones. The lack of its direct feeding following the β-decay of ^{117}Ag^{g,m} is consistent with the suggested spin and configuration. We propose $5/2^-$ spin (instead of $7/2^+$) and $4^+_1 \otimes h_{11/2}$ configuration for the 427.1 keV state of ^{119}Cd. This level decays predominantly to the first $9/2^-$ and $7/2^-$ ones and fits the chain of $5/2^-_1$ states: 1326.6 keV (^{111}Cd), 855.0 keV (^{113}Cd), 719.9 keV (^{115}Cd), and 605.7 keV (^{117}Cd).

The correspondences indicated in Figs. 4 and 5 are based on careful consideration of the various excitation and decay properties of the individual levels. Some reaction types populated selectively a minor portion of the levels which made it possible to find easily the corresponding pairs. The best example is the β-decay of the Ag *isomers*. These reactions feed selectively states which contain significant $[\pi g_{9/2}]^2 \otimes \nu g_{7/2}$ amplitudes.

One can see two evolution patterns in Figs. 4 and 5. In a part of the chains the corresponding levels lie at higher energies for larger neutron numbers. These states have $g_{7/2}$ or $d_{5/2}$ parentage. Since these subshells are filled, increasing energy for increasing neutron numbers is necessary to create a $g_{7/2}$ or $d_{5/2}$ hole. On the contrary, filling of the higher-lying $d_{3/2}$ and $h_{11/2}$ orbits tends to be easier when they are nearly empty ($N<71$). This results in the lowering of the states of such parentage. These facts allow an easy distinction between levels having the same spin but $d_{3/2}$ and $d_{5/2}$ (or $g_{7/2}$) parentage.

The ^{111,113}Cd level schemes are nearly complete below 1.5 MeV. ^{111}Cd has five "excess" levels between 0.7 and 1.2 MeV, *viz.*, the 700, 754.9 855.6

1020.7 and 1130.4 keV ones seen in CELI experiments[16,17], which have no corresponding pairs in the heavier cadmium isotopes. Similarly, we do not find corresponding pairs to the 738 keV 864.3 keV levels which have been observed in various reactions but not by Baskova *et al.* A level, however, is strikingly missing, *viz.*, the one which would correspond to the 760 keV (^{113}Cd) and 803 keV (^{115}Cd) $1/2^+$ states which were fed only in (d,p) and (d,t) reactions[19,31]. It is unclear why low-lying, low-spin states such as the 700, 736, 754.9, 855.6, 864.3, 1020.7, 1130.4 (^{111}Cd), 760, 1195.3, and 1430 keV (^{113}Cd) ones have not been fed in the experiments of Baskova *et al.*

^{113}Cd has no "excess" levels below 1 MeV. Instead, corresponding pairs to the aforementioned seven states of ^{111}Cd as well as to the 507.3 keV (^{115}Cd) and 426.2 keV (^{117}Cd), $3/2^+$ levels, which decay exclusively to the ground state, are missing. The level schemes of $^{115-119}$Cd are incomplete, even below 1 MeV, especially in the $J>5/2$ spin region. (n,γ) and improved (d,p) studies could considerably widen our knowledge upon these nuclides.

VI. Closing remarks

This Report illustrates the complexity of the level structure of ^{111,113}Cd. Very strong configuration mixing was found in both nuclides, even at low energies. Up till now, significant features of these nuclides could not be accounted for by model calculations, *e. g.* the magnetic moment of the ground state, the lack of collectivity for levels of $d_{3/2}$ and $d_{5/2}$ parentage, and the strong suppression and compression of the antialigned unique-parity states. New calculations using the interacting-boson-fermion-model are in progress to shed light on the unexplained details.

Apart from demonstrating the problem in explaining the level scheme of ^{111,113}Cd on the basis of existing calculations, the most interesting results of this Report are, in our opinion, the identification of numerous antialigned levels as well as of a group of isolated positive-parity states, which exhibit intruder-like properties. The quantitative description of these levels is, no doubt, very difficult, but would be crucial. Little is known about the n-quasiparticle states. Although various three-quasiparticle states below 2 MeV are expected, only the $[\pi g_{9/2}]^2 \otimes \nu g_{7/2}$ configuration has been recognized.

The odd Cd isotopes do not belong to those nuclides which are frequently investigated. The "result" of the moderate interest is that our knowledge on these nuclides is quite incomplete. We have shown that their structure is not so simple as was thought before and it is worthwhile to investigate them further.

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Table captions

Table I. Levels of ^{111}Cd. The transition energy and intensity data are from Ref. 1. The level energies are calculated as described in section III/b. The explanation of the symbols is as follows. Column 1: asterisk: new level introduced by us; question mark: uncertain level; parenthesis: the level was populated neither in (n,n'γ) nor in (n,γ) reaction but has been fed in other nuclear reactions. Column 3: D: doublet or more complex multiplet; M: multiple placement. Column 4: A: the (n,γ) peak is doublet as deduced from the anomalously low (n,n'γ)/(n,γ) intensity ratio. Column 5: cross: the reported multipole mixing ratio is calculated by us. Cross references (column 6): A: (α,3nγ) reaction, B_0: $^{111}Ag^g$ β^--decay, B_1: $^{111}Ag^m$ β^--decay, C: Coulomb-excitation, D: (d,p) and/or (d,t) reaction, E: ^{111}In EC decay, F: (d,d') reaction, G: (p,p') reaction, H: (^3He,2nγ) reaction, J: (n,n'γ) reaction, K: (n,γ) reaction, L: (n,γ) reaction primary transitions, M: (γ,γ') reaction. Energies in keV.

Table II. Levels of ^{113}Cd. For the explanation of symbols, see the caption to Table I. The only alteration is that B_0 and B_1 stand for the β^--decay of $^{113}Ag^g$ and $^{113}Ag^m$, respectively.

Table III. B(E2) values of the $7/2^-_1 \rightarrow 11/2^-_1$ transitions in odd Cd isotopes. A: deduced from the calculated B(E2) value, B: deduced from the total half-life value of Ohya *et al.*[34], and the branching ratio reported in Table II, C: from Ref. 34, D: from Ref. 48, E: from Ref. 49, F: estimated, G: recalculated value, H: fix point for the fitting.

Table IV. Integral cross section values for the $^{111}Cd(\gamma,\gamma')^{111}Cd^{m}$ reaction. The cross section values reported in Refs. 39-43 were obtained by supposing a single activation level around 1.33 MeV.

Figure captions

Fig. 1. Comparison of experimental, theoretical, and empirical B(E2) values of the $7/2^-_1 \rightarrow 11/2^-_1$ transitions in odd Cd isotopes.

Fig. 2. Low-lying unique-parity levels in ^{111,113}Cd as a function of core spin and alignment. R is the core spin, j is the particle angular momentum which is actually 11/2, and n is related to the angle between $\vec{R}$ and $\vec{j}$.

Fig. 3. Energies of selected unique-parity states of ^{111,113}Cd as a function of spin.

Fig. 4. Systematics of the lowest-lying levels (E<900 keV) of the medium-weight odd Cd isotopes. The 967.8, 1185.7, and 1326.6 keV states of ^{111}Cd are displayed in this figure because the levels corresponding to them are lying below 900 keV.

Fig. 5. Systematics of low-lying levels (900 keV<E<1700 keV) of medium-weight odd Cd isotopes. The 967.8, 1185.7, and 1326.6 keV states of ^{111}Cd are shown in Fig. 4.

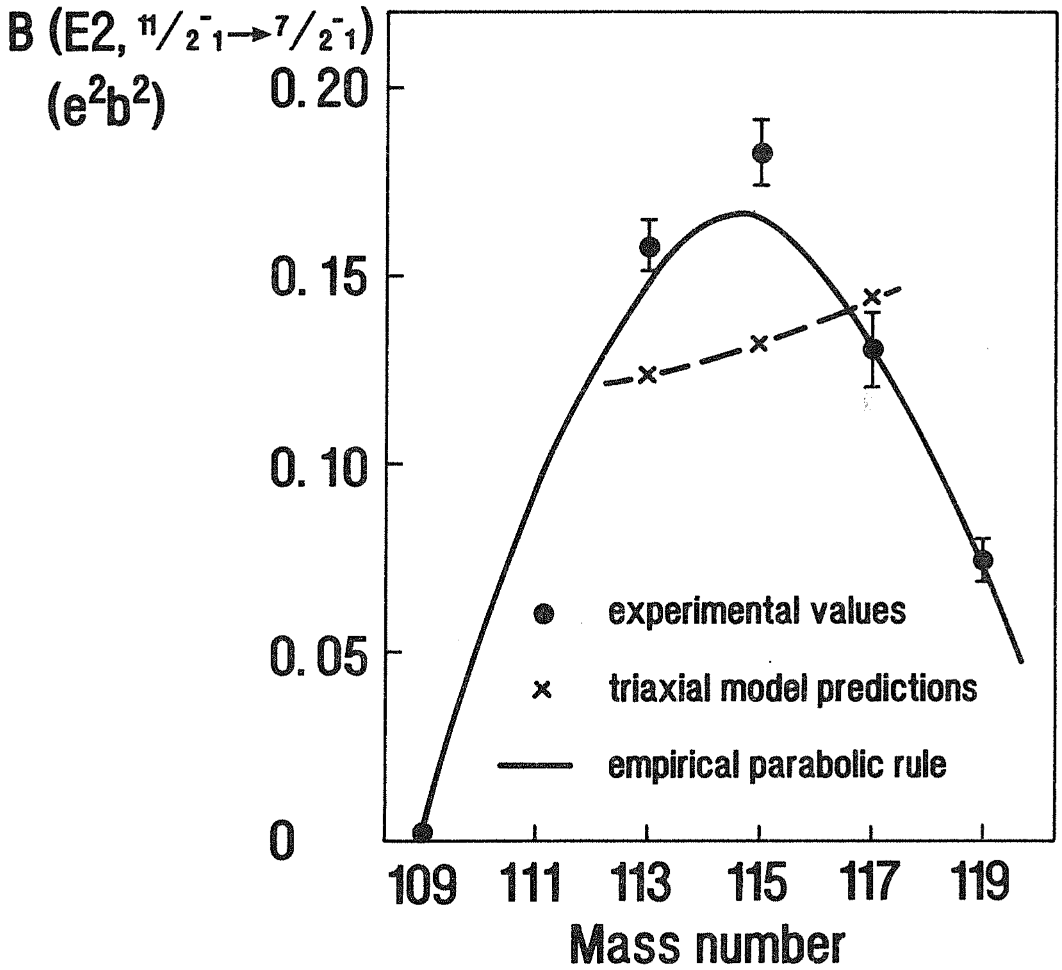
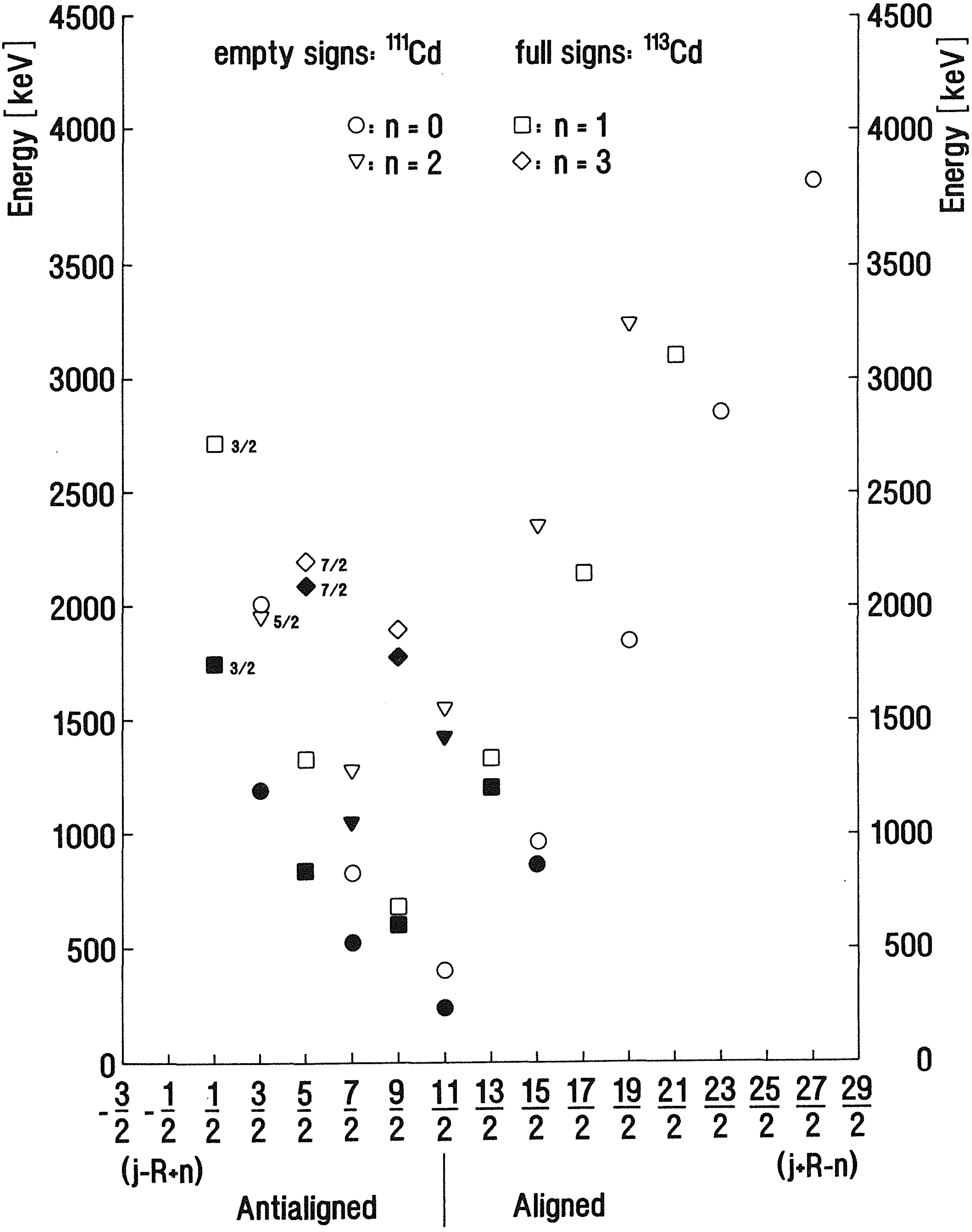

B (E2, 11/2⁻1→7/2⁻1)
(e2b2)
0.20
0.15
0.10
0.05
0
experimental values
triaxial model predictions
empirical parabolic rule
109
111
113
115
117
119
Mass number

Fig. 1.



Energy [keV]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
empty signs: 111Cd
full signs: 113Cd
○: n = 0
□: n = 1
▽: n = 2
◇: n = 3
3/2
7/2
7/2
5/2
3/2
-3/2 -1/2 1/2 3/2 5/2 7/2 9/2 11/2 13/2 15/2 17/2 19/2 21/2 23/2 25/2 27/2 29/2
(j-R+n)
(j+R-n)
Antialigned
Aligned

Fig. 2

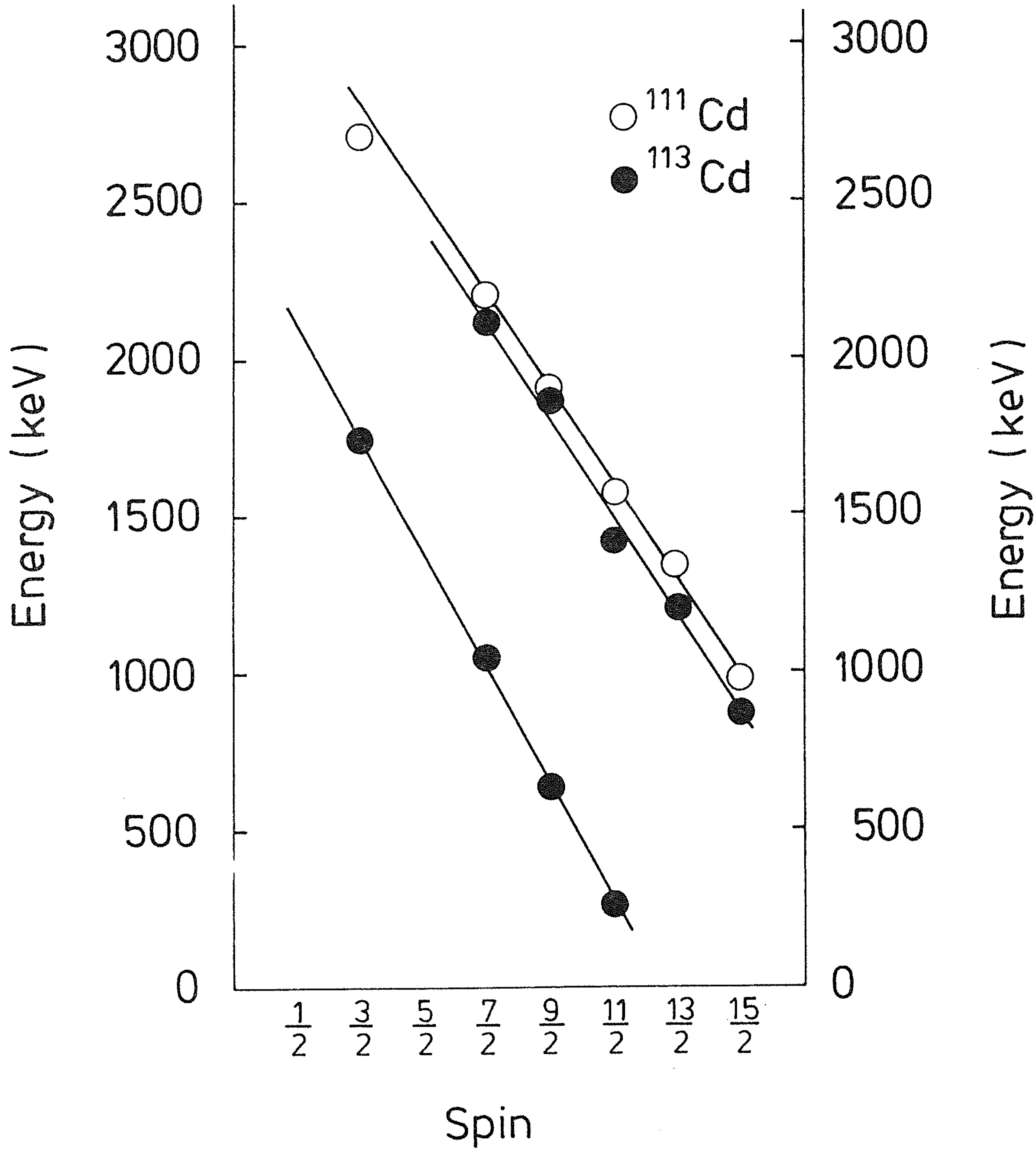

3000
2500
2000
1500
1000
500
0
Energy (keV)
111 Cd
113 Cd
1/2
3/2
5/2
7/2
9/2
11/2
13/2
15/2
Spin

Fig. 3

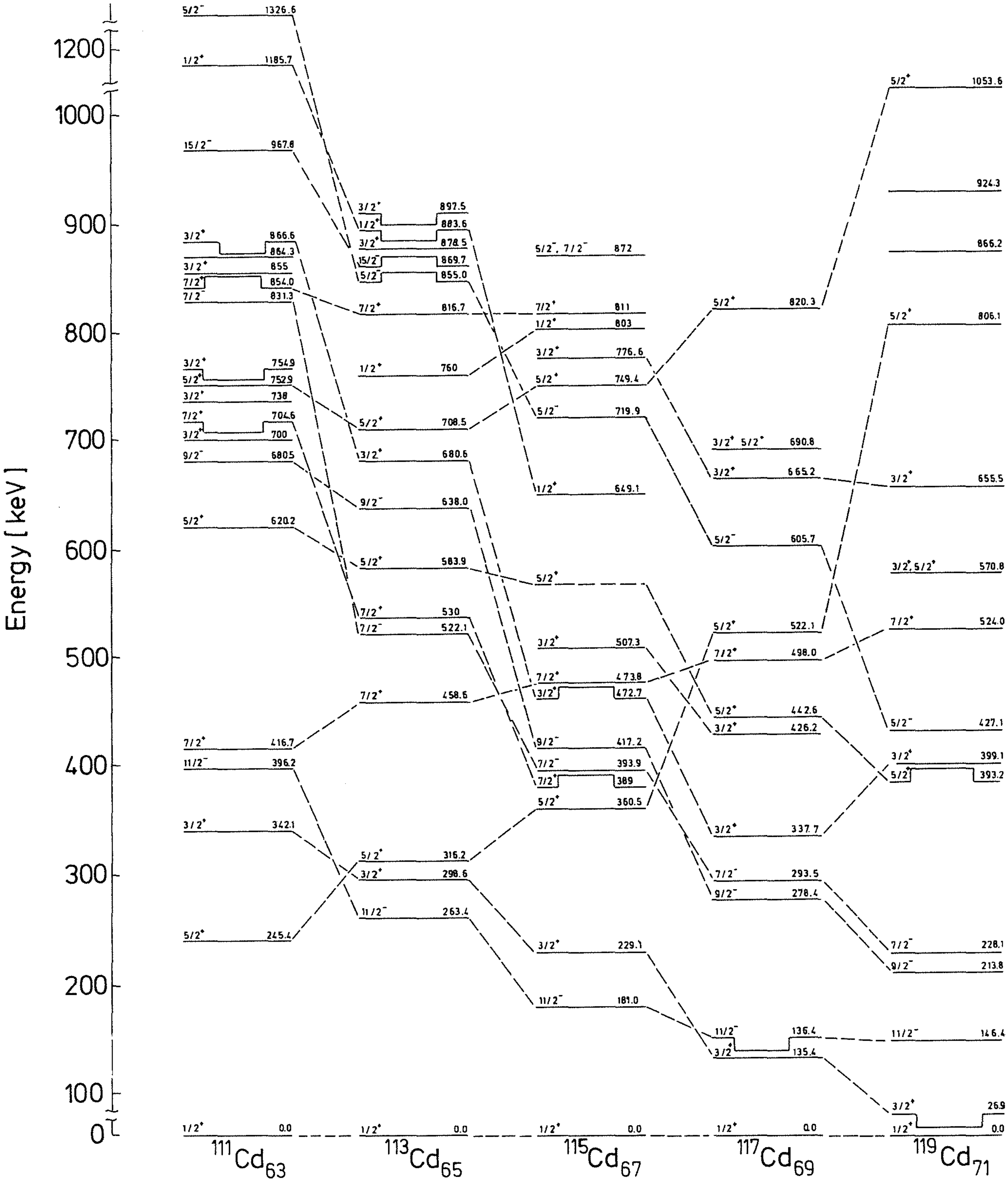


Fig. 4.

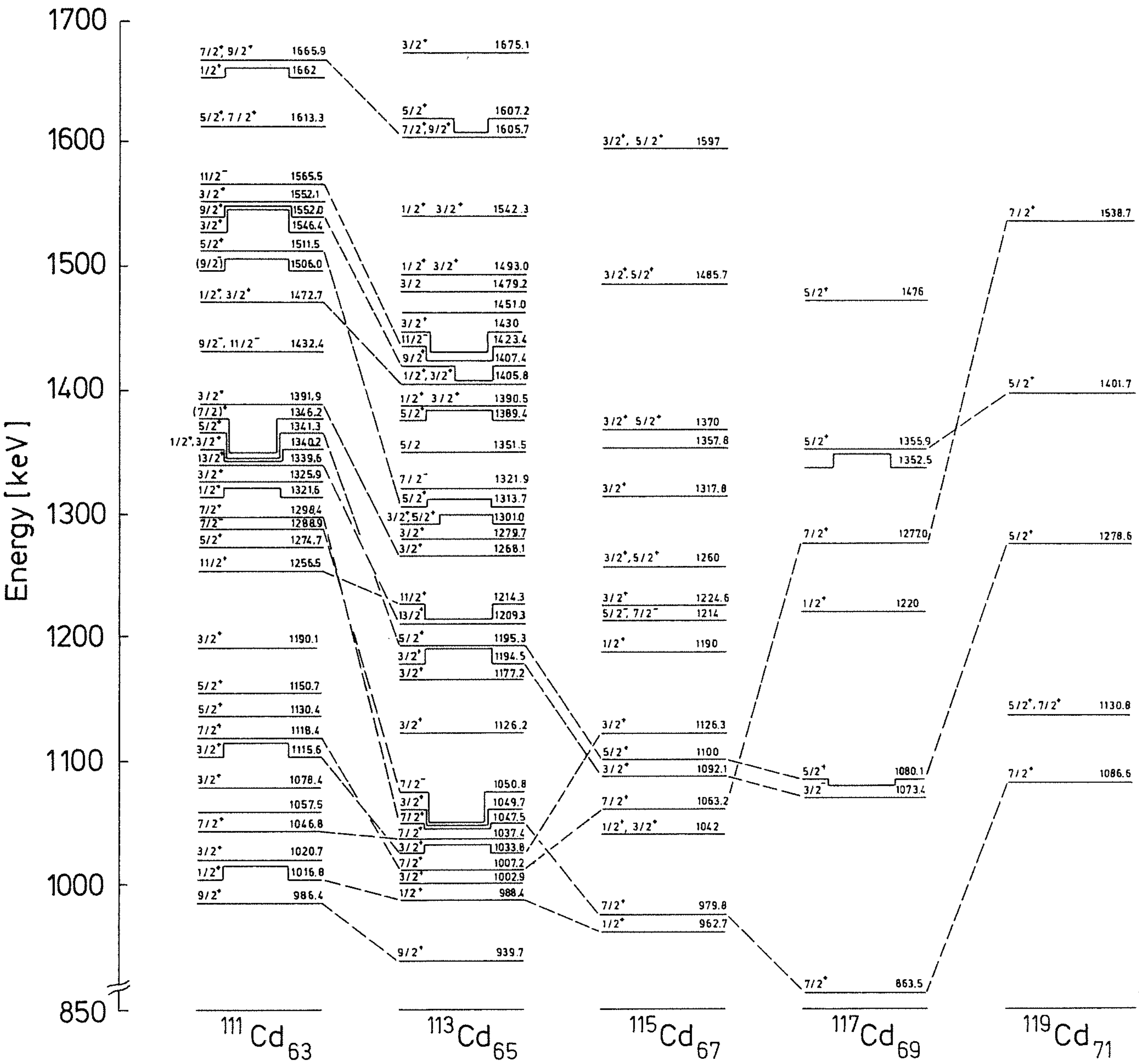

Energy [keV]
1700
1600
1500
1400
1300
1200
1100
1000
850
7/2+, 9/2+ 1665.9
1/2+ 1662
5/2+, 7/2+ 1613.3
11/2− 1565.5
3/2+ 1552.1
9/2+ 1552.0
3/2+ 1546.4
5/2+ 1511.5
(9/2) 1506.0
1/2+, 3/2+ 1472.7
9/2−, 11/2− 1432.4
3/2+ 1391.9
(7/2)+ 1346.2
5/2+ 1341.3
1/2+, 3/2+ 1340.2
13/2 1339.6
3/2+ 1325.9
1/2+ 1321.6
7/2+ 1298.4
7/2− 1288.9
5/2+ 1274.7
11/2+ 1256.5
3/2+ 1190.1
5/2+ 1150.7
5/2+ 1130.4
7/2+ 1118.4
3/2+ 1115.6
3/2+ 1078.4
1057.5
7/2+ 1046.8
3/2+ 1020.7
1/2+ 1016.8
9/2+ 986.4
111Cd63
3/2+ 1675.1
5/2+ 1607.2
7/2+, 9/2+ 1605.7
1/2+ 3/2+ 1542.3
1/2+ 3/2+ 1493.0
3/2 1479.2
1451.0
3/2+ 1430
11/2− 1423.4
9/2+ 1407.4
1/2+, 3/2+ 1405.8
1/2+ 3/2+ 1390.5
5/2+ 1389.4
5/2 1351.5
7/2− 1321.9
5/2+ 1313.7
3/2+, 5/2+ 1301.0
3/2+ 1279.7
3/2+ 1268.1
11/2+ 1214.3
13/2+ 1209.3
5/2+ 1195.3
3/2+ 1194.5
3/2+ 1177.2
3/2+ 1126.2
7/2− 1050.8
3/2+ 1049.7
7/2+ 1047.5
7/2+ 1037.4
3/2+ 1033.8
7/2+ 1007.2
3/2+ 1002.9
1/2+ 988.4
9/2+ 939.7
113Cd65
3/2+, 5/2+ 1597
3/2+, 5/2+ 1485.7
3/2+ 5/2+ 1370
1357.8
3/2+ 1317.8
3/2+, 5/2+ 1260
3/2+ 1224.6
5/2−, 7/2− 1214
1/2+ 1190
3/2+ 1126.3
5/2+ 1100
3/2+ 1092.1
7/2+ 1063.2
1/2+, 3/2+ 1042
7/2+ 979.8
1/2+ 962.7
115Cd67
5/2+ 1476
5/2+ 1355.9
1352.5
7/2+ 1277.0
1/2+ 1220
5/2+ 1080.1
3/2− 1073.4
7/2+ 863.5
117Cd69
7/2+ 1538.7
5/2+ 1401.7
5/2+ 1278.6
5/2+, 7/2+ 1130.8
7/2+ 1086.6
119Cd71

Fig. 5.

Table I. ^{111}Cd levels

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
0.0	$1/2^+$					
245.40(3)	$5/2^+$	245.40(3)	253(12)/274(25)	E2	A - L	
342.12(3)	$3/2^+$	342.12(3) 96.7(2)	100(5)/100 3.1(6)/(-)	M1 +E2, δ = 0.39(2) M1 + E2	B_0, B_1, C, D, F, G, H, J, K, L	
396.22(3)	$11/2^-$	150.77(20)	22(2)/(-)	E3	A, D - K	The level energy is taken from Refs. 2.
416.69(4)	$7/2^+$	171.29(3)	56(5)/57(6)	M1 + E2, δ = -0.17(5)	A, D-H, J, K	
620.16(4)	$5/2^+$	620.31(20)^D 374.75(5) 278.04(5) 203.29(12)	<36(5)/<38(4) 11.1(11)/12.5(9) 2.2(2)/3.0(4) 0.26(5)/0.30(6)	E2 M1 + E2, δ = 2.8(5) M1 + E2, δ = -0.45 (+25,-13) or -1.2(+2,-4)	B_0, B_1, C-H, J, K	
680.50(6)	$9/2^-$	284.28(5)	37(2)/29(3)	M1 + E2, δ = 0.16(1)	J, K	
(700.	$3/2^+$	700.			C)	
704.61(12)*	$7/2^+$	(24.1)		E1	D, J, K	
(736	$3/2^+$	(736) (31)		M1 + E2 E2	F, G, M)	Jπ : L = 2 in (p, p').
752.86(6)	$5/2^+$	752.85(10)^D 507.6(3) 410.77(10) 336.16(10)	<9.1(2)/7.9(8) 16(6)/(-) 5.2(5)/5.4(9) 1.9(5)/3.2(6)	E2 M1 + E2, δ = -0.36(2) or 4.9(2) M1 + E2, δ = -0.05(3) M1 + E2	B_1, C, H, J, K	

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
(754.9	$3/2^+$	754.8(7) 509.0(7) 413.0(10)			B_0, C, H)	
831.28(11)*	$7/2^-$	435.06(10) (150.8	9(2)/5.5(9) masked	E2 M1 + E2)	J, K	Jπ : from (n, n'γ)/(n, γ) and systematics
854.0(1)	$7/2^+$	608.58(20) (511.9 437.21(20)[D]	4.0(9)/12.3(25)[A] masked $<$3.3(8)/2.0(6)	M1 + E2 E2) M1 + E2	C, H, J, K	
(855.6	$3/2^+$	855.6			C)	
(864.3	$3/2^+$	864.3 619.3 522.4			B_0, D, H)	
866.56(8)	$3/2^+$	866.61(10) 621.2(4) 524.33(20)[D] 449.81 (10)	5.1(7)/($<$)16(5)[A] 8(2)/(-) 2.8(6)/1.8(2) 0.39(12)/0.47(14)	M1 + E2, δ = -0.10(5) or -1.42(7) M1 + E2 M1 + E2, δ = 2.4(4) E2	B_0, C, D, J, K, L, M	
967.8(5)	$15/2^-$	571.6(5)	1.5(6)/ -	E2	A, H, J	
986.43(11)	$9/2^+$	741.03(10) 569.05[D]	2.7(5)/0.80(12) $\leqslant$16(3)/$\leqslant$7.3(9)	E2 M1 + E2	A, C, H, K, L	
1016.75(9)	$1/2^+$	1016.77(10) 771.2(5)[D] 263.84(15)	8.7(8)/14.2(14) $<$0.65(18)/0.98(37) 0.72(14)/ -	M1 + E2 E2 E2	K, L, M	
(1020.7	$3/2^+$	1020.7 775 165			C)	

Level	J^{π}	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
1046.78(7)	7/2$^+$	801.43(20)	2.1(4)/ -	M1 + E2	C, H, J, K	
		704.66(15)	4.2(9)/6.0(15)[A]	E2		
		(629.85(20)	0.47(8)/ -	M1 + E2)		
		426.65(15)	0.61(12)/0.46(14)	M1 + E2		
		293.91(8)	0.27(5)/ -	M1 + E2		
1057.5(2)*(?)	(3/2)$^+$	1057.4(4)	0.48(8)/ -		J, K	
		811.95(15)	0.94(18)/2.0(7)			
		715.65(15)	3.7(7)/3.7(6)			
		437.21(20)[D]	$<$3.3(8)/$<$2.0(6)			
		304.4(3)	0.08(3)/ -			
1078.33(7)	3/2$^+$	1078.35(10)	5.8(9)/7.1(9)	M1 + E2, δ = 0.27(+5,-3)	J, K, L	
		832.91(10)	6.2(6)/9.4(8)	M1 + E2, δ = 0.20(4)		
		458.15(20)	0.38(7)/1.8(4)	M1 + E2		
		211.7(3)	0.19(8)/0.40(8)			
1115.55(10)	3/2$^+$	1115.57(15)	6.2(12)/6.8(9)	M1 + E2, δ = -0.17(3)	C, H, J, K, L	
		773.40(20)	3.1(10)/3.4(9)	M1 + E2, δ = 2.8(+6, -4)		
		495.38(15)[D]	$<$1.6(2)/$<$1.5(3)	M1 + E2, δ = 0.09(9) or -9(+60, -4)		
1118.44(7)*	7/2$^+$	873.06(10)	3.6(4)/3.0(6)	M1 + E2, δ =0.25(5)$^+$	J, K	J^{π} from I(n, n'γ)/I(n, γ). The experimental angular correlation coefficients of the 873 keV transition are consistent with the 7/2$^+$ assignment.
		776.29(10)	3.1(7)/2.8	E2		
		701.6(5)[D]	$<$1.6(6)/$\leqslant$6.8(15)	M1 + E2		
		498.30(15)	0.84(16)/ -	M1 + E2		
		365.5[D]	0.36(15)/ -	M1 + E2		
(1130.4	5/2$^+$	1130.4		E2	C)	
1150.74(10)*	5/2$^+$	1150.74(10)	0.91(9)/1.3(2)	E2	(D), J, K, M	
		446.13(5)	10.5(5)/11.6(9)			

Level	J^π	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
1185.72(10)*	$1/2^+$	1185.72(10) (843.6	5.6(6)/9.7(9) masked	M1 + E2 M1 + E2)	D, J, K	L = 0 in (d, p), (d, t). I(n, n'γ)/I(n, γ) and P_{exp} consistent with $J^\pi = 1/2^+$.
1190.1(1)	$3/2^+$	1190.13(15) 569.05^D 323.41(25)	0.31(6)/0.75(19) ≤16(3)/<7.3 0.24(7)/ -	M1 + E2, δ = 0.19(3) or -2.9(3) M1 + E2 M1 + E2	J, K, L	
1256.45(10)	$11/2^+$	839.85(10) 269.74(15)	2.0(2)/< 0.80(28) 0.58(11)/ -	E2 M1 + E2	A, C, H, J, K	
1274.73(8)	$5/2^+$	1029.35(10) $932.56(15)^D$ 858.0(4) 420.70(20)	2.0(2)/1.8(4) <3.9(7)/(<)2.4(6) 0.35(16)/0.30(8) $0.46(9)/\leq 1.4(5)^A$	$M1 + E2, \delta = 0.60(10)^+$ $M1 + E2, \delta = 0.28(5)^+$ M1 + E2 M1 + E2	H, J, K	The experimental angular correlation coefficients of the 933 and 1029 keV transitions consistent with $5/2^+$ but inconsistent with $7/2^+$ spin-parity assignment.
1288.9(3)*	$7/2^-$	892.2(10) 608.4(3) 457.8(6)	-/0.21(8) -/≈8 -/≈1.4		K	
1298.5(2)	$7/2^+$	1054.14^D 881.63(20) 467.42(25)	<3.1(6)/<2.4(7) 1.7(4)/0.90(36) 0.2(6)/ -	(E2) (M1 + E2) E1	H, J, K	
1321.59(10)*	$1/2^+$	1321.59(10) 979.5(5)	3.6(4)/6.2(9) 0.15(6)/ -	M1 + E2 M1 + E2	J, K, (L)	I(n, n'γ)/I(n, γ) and P_{exp} are consistent with $J^\pi = 1/2^+$.
1325.93(10)	$3/2^+$	1325.93(10) $(621.3^D$	1.6(2)/3.0(4) ~5.5/~8	M1 + E2, δ = 0.05(5) or -1.6(3) E2)	D, J, K, L, M	
1326.65(9)*	$5/2^-$	984.55(20) 646.13(10) $495.38(15)^D$	0.40(13)/0.11(8) 4.2(4)/≤9.6(14) <1.6(2)/<1.5(3)	E1 E2 M1 + E2	J, K	
1339.6(3)	$13/2^-$	943.42(15) 371.90(20)	1.2(2)/0.12(4) 0.04(2)/ -	M1 (+E2) M1 + E2	A, H, J, K	

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
1340.23(16)	1/2⁺, 3/2⁺	1340.27(20)	3.2(6)/4.4(6)		J, K, L	
		720.02[D]	<3.3(7)/<4.8(7)			
		588.2[D]	⩽0.97(2)/<0.60(15)			
		323.41(25)	0.24(7)/ -			
1341.30(10)	(5/2)⁺	999.18(10)	3.4(3)/4.7(9)[A]		D, H, J, K	
		924.7(4)	1.8(9)/<1.5			
		588.2[D]	<0.97(2)/<0.60(15)			
1346.22(9)*	7/2⁺	1100.83(15)	1.3(3)/<4.8(12)[A]		J, K	
		1004.14(15)	0.32(9)/ -			
		929.43(20)	1.3(4)/0.63(19)			
		725.4(4)	masked/1.7(6)			
1391.82(7)	3/2⁺	1391.77(25)[D?]	0.54(11)/0.43(9)	M1 + E2	J, K, L	
		1146.46(10)	3.5(4)/4.2(6)	M1 + E2, δ = 0.16(2) or 14(+30, -5)		
		1049.67(10)	1.3(2)/2.1(5)	M1 + E2, δ = 0.16(6) or 2.3(+5,-3)		
		638.91(15)	0.26(7)/0.38(13)	M1 + E2		
1432.4(1)*	9/2⁻, 11/2⁻	1036.20(15)[D?]	(<)1.4(3)/⩽0.62(12)	M1 + E2	J	
		(752. masked	≈2.5/ ?	M1 + E2)		
		601.16(15)	0.24(5)/ (-)			
1472.7(2)	(1/2)⁺	1472.8(3)	1.0(2)/3.1(8)		J, K, L	
		1130.56(15)	1.8(2)/3.6(7)			
		720.02[D]	⩽3.3(7)/⩽4.8(7)			
		455.01[D]	<0.23(6)/ -			
1506.04(10)*	(9/2)⁻	1109.55(20)	1.1(2)/0.66(23)		J, K	
		825.64(10)	2.0(2)/(<)1.2(2)			

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
1511.5(1)	$5/2^+$	(1511.4(3)	0.10(3)/ -	E2)	H, J, K	Jπ : $5/2^+$ from (^{3}He, 2nγ).
		1266.58(25)[M]	1.3(3)/0.16(5)			
		1094.8(4)	0.50(15)/ -	M1 + E2		
		891.25(15)	0.98(10)/0.21(5)			
		393.24(20)	0.57(10)/ -	M1 + E2		
1546.40(14)	$3/2^+$	1547.0(4)	0.52(26)/ (-)	M1 + E2	(D), J, K, L	
		1301.22(20)	0.58(12)/0.80(28)	M1 + E2		
		926.3(4)	0.58(17)/ (-)	M1 + E2		
		793.39(10)	0.69(15)/1.2(2)	M1 + E2, $-1.25<\delta<-0.50$		
1551.9(3)	$(9/2^+)$	1135.16(20)	0.69(14)/0.10(5)	M1 + E2	C, H, J, K	
		932.56(15)[D]	~1.5/ ?	E2		
1552.1(1)	$3/2^+$	1552.09(10)[D?]	<1.02(15)/0.96(19)	M1 + E2, $1.0<\delta<3.7$	(D), J, K, L	
		1306.87(20)	0.67(13)/1.6(4)	M1 + E2		
		1209.9(4)	1.2(3)/4.0(11)	M1 + E2		
1565.9(4)	$11/2^-$	1169.7(4)	0.41(8)/ -		A, H, J	
		(598.3)				
1613.33(15)*	$5/2^+$, $7/2^+$	1367.87(25)	0.79(24)/0.73(26)		J, K	Jπ : from I(n, n'γ)/I(n, γ).
		1271.08(25)	1.1(3)/0.92(22)			
		(1197.1(7)?	-/0.52(15)			
		993.30(20)	0.22(6)/<0.65(26)[A]			
		758.8(8)	masked/0.29(11)			
		746.6(4)	0.11(3)/≤2.7[A]			
1624.2(6)*?	$1/2^+$?	1378.2(6)	- /1.6(4)		K	Probably fed from the 2016.0 keV level. The existence of this level is uncertain.
		1282.7(7)	- /1.4(5)			
1662(2)*	$1/2^+$				D, L	
1665.92(25)*	$7/2^+$, $9/2^+$,	1249.11(20)	0.48(15)/≤0.50[A]		A, H, J, (K)	
		679.65(20)	0.84(3)/≤1.9(5)			

Level	J^π	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
1683.1(2)*	7/2, 9/2	1437.60(20) 1266.58(25)^{M} 976.95^{D} 408.48(25)	0.36(7)/0.25(8) 1.3(3)/0.16(5) ~0.6/ ? 0.26(5)/ -		(F, G) J, (K)	The level may correspond to 1692 keV one seen in (p, p') with L = 3 and in (d, d'). If so, $J^\pi = 7/2^-$. J^π from I(n, n'γ)/I(n, γ).
1691.95(20)*	$(1/2)^+$	1691.95(20) 1349.3(9) 939.3(6)	1.4(1)/3.5(5) - /0.35(13) - /0.52(15)		J, K	J^π from I(n, n'γ)/I(n, γ) and weak population in (n, n'γ).
1717.5(3)	$3/2^+$	1717.65$^{D(?)}$ 1471.8(8) 1097.3(3) (964.5(5) 701.3(7) 601.9(5)	0.60(12)/1.6(3) ? / ≤3.1(8) 0.62(12)/masked 0.40(12)(-) ≤1.6/ ≤6.8 - /0.60(18)		D, J, K	L = 2 in (d, p), $3/2^+$ preferred.
1740.00(20)	$1/2^+$ $3/2^+$	1740.0(8) 1494.60(20)	- /0.36(14) 1.5(4)/2.7(4)		C, J, K, L	Baskova et al. prefer $3/2^+$, the I(n, n'γ)/I(n, γ) ratio and population data suggest $1/2^+$ spin.
1789.54(18)	$3/2^+$	1789.59(25) (1544.7(4) 1447.36(25) 1036.1(5)	0.28(6)/0.83(25) 0.42(20/ <1.7(5)) 0.50(14)/0.80(25) ≤1.4/0.62(12)		J, K; L	
1800.92(15)*	$7/2^-$	1404.68(20) (1120 969.66(20) 235.3(3)	0.56(11)/ - ?) 1.06(11)/0.54(11) 0.23(8)/0.20(6)		G, J, K	
1826.7(3)	$9/2^+$	839.85(10)^{D} 779.95(15)	0.34(12)/ - ≤2.0/ -		H, J	
1828.1(2)	$3/2^+$	1828.0(3) 1486.01(25)	0.51(20)/0.75(22) 0.69(21)/1.5(4)		J, K, L	

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
1842.54(20)	$3/2^+$, $1/2^+$	1842.54(20) (1598.52[D] (1500.6(8)[M] 1222.0(4)[M] 975.6(4)	0.71(21)/3.3(5) $<$0.35(9)/$<$2.0(5)) - /0.67(20)) 0.25(12)/0.95(35) $\leqslant$1.3/1.4(2)		J, K, L	
1849.1(2)*	$3/2^+$, $5/2^+$	1849.15[D?] 1506.6(4) (1432.3(6) 733.5(9)	0.87(25)/1.5(3) 0.61(19)/1.7(6) - /0.54(11) - /0.35(5)		J, K	
(1851.1	$19/2^-$	885.3	-		A, H)	
1895.02(28)*	$9/2^-$	1498.80(25) 554.9(4)	0.67(19)/(-) 0.07(3)/ -		J	
1907.4(3)	(7/2- $11/2)^+$	1490.7(3) 1054.14[D]	0.51(25)/ - $\leqslant$3.1/$\leqslant$2.4		H, J	
(1921.2	$(13/2)^+$	934.8			A, H)	
1971.76(13)*	$7/2^-$	1575.52(15) 1291.5(3) 1140.53(20)	1.2(3)/0.35(12) 0.61(18)/masked 0.68(14)/masked	E2	G, J, K	Jπ from (p, p').
1974.8(2)*	$3/2^+$	1632.7(2) 1354.80(25) 1222.0(4)[M] 958.17[D] 784.69(25)	1.7(3)/5.5(9) 0.80(24)/ - 0.25(12)/0.95(35) $\leqslant$0.45(11)/0.48(10) 0.11(3)/ -		D, J, K	Jπ from (d, p).

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
1992.77(13)*	5/2⁻,	1312.24(15) 1161.6[D] 666.19(20)	1.2(3)/ - 0.96(18)/(0.22(7)) 0.70(21)/(0.50(18))		J	The strong population and the lack of transition to the 396 keV state prefer 5/2⁻.
2006.0(2)*	3/2⁻	2005.6(4) 1664.8(8) 1174.0(8) 680.0(5)	- /1.3(3) (0.09(4))/0.23(11) (-)/0.60(24) (-)/(<)1.9(5)		K	
2016.0(5)*	3/2⁺	2016.2(8) 1263.0(8) 900.2(10) (391.8(5)	- /0.95(31) (0.05)/1.0(3) (0.34)/0.20(8) - /1.9(4))		D, K	
(2038.07(20)*	(3/2)⁺	2037.9(6) 1793.67(20) 1696.2(5) (1332.3(8)	0.18(6)/0.43(12) 0.56(17)/1.4(5) 0.9(4)/⩽1.9 - /0.60(12)		J, K	Uncertain level.)
2045.2(3)*	(1/2)⁺	2045.2(3) 704.7[D] 493.1(5) 420.8(6) 353.4(5)	(0.32(9)/2.2(3) (-)/~2.0 - /4.4(7) (-)/~1.0 (-)/1.8(3)		K	
2097.3(2)*	7/2⁺, 5/2⁺	1391.8(3) 1344.5(5) 1243.3(2) 979.5(5) 907.02(20)	(⩽0.54)/(⩽0.43) 0.53(25)/0.48(19) 1.4(4)/1.5(3) 0.15(6)/ - 0.32(6)/0.40(16)		J, K	
2134.7(3)*	(1/2, 3/2)⁺	1888.8(10) 1792.67(20) (1717.65[D] 808.5(3) 662.7(6)	- /0.70(25) 0.56(17)/1.4(5) ⩽0.60/⩽1.6 0.23(11)/1.1(4) - /0.80(28)		D, J, K	

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
(2147.6	$17/2^-$	1179.4 808.8			A, H)	
2154.2(2)*	$5/2^+$, $7/2^+$	1909.03(25) 1812.1(4) 1737.36(20) 1038.7(3) 964.5(5)	0.21(4)/ - 0.12(6)/ - 0.67(18)/0.46(16)? 0.12(4)/ - 0.40(12)/ -		J, K	
2165.6(5)*	$1/2^+$, $3/2^+$	2165.6(8) 1545.[D] 1299.0(5)	(-) /0.99(32) (-) /<1.7(5) - /3.0(9)		K	
2196.2(2)* ?	$(7/2^-)$	1515.6(2) 1365.2(4)?	0.93(18)/0.56(14) 0.71(21)/?		J	
2236.2(2)*	(1/2- $5/2)^+$	2236.4(3) 1990.8(5) 1483.4(3) 1219.3(3) 1157.7(10) 762.9(10)	0.32(6)/0.85(21) 0.16(8)/0.37(13) 0.13(5)/0.36(15) 0.24(6)/0.85(26) - /0.10(5) - /0.21(7)		J, K	
2242.7(2)*	(3/2- $7/2)^+$	1900.68[D] 1622.46(25) 1226.0(3) 2280.0(6)	(<)0.82/0.68(31) 0.40(12)/0.61(21) 1.7(5)/1.7(6) -/1.2(3)		J, K	
2280.8(2)	$1/2^+$, $3/2^+$	1938.6(3) 1660.6(3) 1091.0(3)	0.15(3)/0.50(18) 0.43(15)/1.5(5) 0.21(6)/0.41(14)		D, J, K, L	

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
2325.5(5)?	$1/2^+$, 3/2	2325.9(10)	- /0.21(8)		J, K, L	Uncertain level.
		1983.4(5)	0.17(7)/0.30(11)			
2383.0(3)*	$7/2^+$, $5/2^+$	(2383.8(7)	0.21(4)/0.56(14))		J, K	
		1966.4(4)	0.43(8)/1.12(23)			
		1528.6(2)	0.62(12)/1.2(3)			
		1317.0(2)	0.36(7)/0.40(14)			
		1197.1(7)	- /0.52(15)			
		1042.2[D]	<0.13/<1.1			
2445.7(4)*	$3/2^+$, 5/2	2103.6[D]	- /2.8(6)		K	
		1826.4[D]	- /1.6(7)			
		1740.0(8)	- /0.36(14)			
		1105.7(6)	- /1.6(4)			
2495.3(3)*	1/2, 3/2	2495.2(8)	- /0.88(18)		K	
		2152.9(5)	0.08(3)/1.11(16)			
		1155.3(8)	≤0.10(3)/0.41(15)			
		1022.5(10)	- /0.51(13)			
2557.1(4)*	1/2, 3/2	2311.7(5)[D,M]	≤0.38(11)/<1.9(4)		J, K, L	The level is fed by the 4417.4(4) keV primary γ-transition.
		1235.1(4)	- /0.83(17)			

Level	J^{π}	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
2568.2(5)*	1/2, 3/2	2568.2(10) 1701.6(8) 1452.2(8)	- /0.46(17) - /1.2(4) - /0.17(5)		K, L	The level is fed by the 4406.1(5) keV primary γ-transition.
2588.4(6)*	$3/2^+$	2245.7(6) 2171.2[D] 1263.1(5) 1248.4(8)	- /1.2(3) - /1.4(3) - /1.0(3) - /0.26(8)		K, L	The level is fed by the 4387.6(8) keV primary γ-transition.
2653.8(4)*	3/2, 5/2	2408.2(10) 2311.7(5)[D,M] 2032.8(8) (1901.2(9)[M]	- /0.34(11) 0.38(11)/<1.9(4) 0.11(3)/0.48(14) ?/<0.68)		J, K	
2692.3(5)*	$5/2^+$, $3/2^+$	2692.2(10) 2275.6(10) 1940.0(10) 1573.7(8)	- /1.08(38) - /0.75(26) - /1.3(5) - /0.35(12)		K	
2710.3(5)*	$3/2^-$	1878.8(8)[M] 1421.0(5) 1384.0(5)	- / 0.60(21) - / 2.2(3) - / 0.35(9)	E2 E2	K, L	The level is fed by the 4265.0(8) keV primary γ-transition.
2714.3(5)*	$(3/2-7/2)^+$	2297.6(4) 1860.6(3) (1697.2(5) 1667.9(7) 1374.6(8)	0.26(5)/1.2(2) 0.12(4)/0.56(22) (-)/1.9(8) - /0.66(16) 0.13(5)/30(9)		J, K	

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
2733.1(14)*	(3/2- 7/2)+	2390.9 1878.8(8)[M] 1617.5(5) 1387.2(5) 993.6(8)[D] 758.8(8) 687.1(10)	(-) /1.5(3) - /0.60(21) - /0.68(22) - /0.77(15) (-)/~0.45 - /0.29(11) - /0.60(21)		K	
2768.3(4)*	3/2+, 5/2+	2768.3(8) 2426.5(6) 2351.4(7) 2016.2(8)	0.12(3)/0.95(27) 0.05(2)/0.31(8) 0.09(3)/0.83(23) - /0.95(31)		J, K	The lack of direct -population suggests 5/2+ rather than 3/2+.
2950.5(5)*	(1/2- 5/2)+	2705.1[D] 2608.0(10) 2330.7(10) 2083.1[D]	- /<2.4(9) - /0.75(26) - /0.14(5) - /<0.93		K	
2977.7(2)*	7/2+, 5/2+	2560.7(4) 2124.0(3) 1930.7(10)	0.34(7)/1.2(3) 0.34(9)/0.84(16) ≪0.50/0.42(16)		J, K	
3076.0(4)*	(3/2- 7/2)+	2829.9(5) 2659.6(6) 2455.8(5) (2059.0(4) 1958.0(5) 1801.8(6) 1410.5(9)	- /0.72(10) - /2.1(4) - /1.5(5) 0.27(8)/1.2(2)) - /0.26(8) (0.20)/0.80(22) - /0.21(7)		K	

Level	Jπ	Depopulating transition (keV)	γ-Intensity (n, n'γ)/(n, γ)	Multipolarity	XREF	Comments
3127.2(3)*	3/2⁺, 1/2⁺	3127.5(10) 2784.8(6) 2507.3(3) 2374.2(5) 1786.5(10)	0.05(2)/0.86(20) (-)/0.80(16) 0.50(14)/1.5(4) 0.09(2)/0.39(12) (-)/0.10(4)		K, L	The level is fed by the 3848.5(8) keV primary γ-transition.

Table II. ^{113}Cd levels

Level	J^π	Depopulating transition	Intensity	Multipolarity	XREF	Comments
0.0	$1/2^+$					
263.35(9)	$11/2^-$	(263.35)			B_0, D, I, J	
298.58(2)	$3/2^+$	298.58(2)	100	M1+E2, δ=0.30(+3, -1)	B-D, F, G, J, L	
316.21(2)	$5/2^+$	316.21(2)	73(4)	E2	B - D, J, L	
458.56(3)	$7/2^+$	142.35(2)	34(3)	M1 + E2, δ= - 0.04(3)	B_1, D, J	
522.07(9)	$7/2^-$	258.72(2)	34(2)	E2	B_0, J	
		205.86(8)	0.42(4)	E1		
(530	$7/2^+$				D)	
583.88(5)	$5/2^+$	583.93(7)^{D}	<33(3)	E2	B-D, F, G, J, L	
		285.19(8)	0.46(4)	M1+E2		
		267.68(6)	0.82(16)	M1+E2		
637.99(10)	$9/2^-$	374.64(3)	13.6(14)	M1+E2, δ =-0.25(2)	B_0, J	
680.57(2)	$3/2^+$	680.59(5)	14.1(9)	E2 or M1+E2 with δ=-1.8(1)	B_0, C, D, F, G, J, L	
		381.96(3)	3.0(3)	M1+E2, δ =0.16(15) or 2.3(7)		
		364.37(3)	3.2(3)	M1+E2, δ =-0.02(7)		
		96.9(2)	~ 0.7	M1+E2		
708.55(2)	$5/2^+$	708.52(5)^{D}	~ 3.3	E2	B_0, B_1, C, J	The intensity of the 708.52 keV transition was calculated by considering Ref. 28.
		409.97(9)	1.0(2)	M1+E2, δ =-0.10(4)		
		392.36(2)	10.(1)	M1+E2, δ =-0.24(4)		
		249.93(6)	1.2(2)	M1+E2, δ =0.34(8) or 5.9(+36, -16)		
(760	$1/2^+$				D)	
816.67(4)*	$7/2^+$	(517.67(15)	0.20(4)	E2)	D, J	
		500.47(3)	6.2(7)	M1+E2, δ =-0.45(16)$^+$		
		358.03(21)	2.2(6)	M1 + E2		
855.02(7)	$5/2^-$	332.97(3)	12.2(11)	M1+E2, δ =-0.27(2)	B_0, J	
		217.00(3)	0.56(6)	E2		
869.68(25)*	$15/2^-$	606.33(25)	1.04(13)	E2	J	

Level	J^π	Depopulating transition	Intensity	Multipolarity	XREF	Comments
878.54(7)*	$3/2^+$	878.62(9)^{D} 580.0^{D} 562.26(9) 419.8(3) 294.52(21)^{M}	(<)8.4(8) <2.5(7) 1.3(2) 0.12(3) 0.62(18)		C, J	
883.60(5)	$1/2^+$	883.60(5) (585.0 567.2(3)?	6.5(6) ~ 2.0) 0.16(3)		B_0, D, J, L	The 585 keV transition was observed in β-γ coincidence by Matumoto et al.[28] and Hnatowich et al[25]. In the (n, n'γ) experiment the peak was masked by the strong 583.93 keV line.
897.46 (5)*	$3/2^+$	598.88(15) 580.0^{D} 438.95 (25) 313.66 (30)	(<)6.0(8) <2.5(7) 0.16 (3) 0.71 (5)		C, D, J	
939.73(5)*	$9/2^+$	623.59(7)$^{D?}$ 481.10(5)	1.8(4) 3.3(3)	E2 M1 + E2	J	
988.44(6)	$1/2^+$	988.43(7) 672.25(15) 307.90(20) 279.80(15)	4.8(3) ~ 0.1 0.05(2) 0.12(2)		B_0, D, J, L	
1002.86(5)*	$3/2^+$	1002.76(9) 322.35(3) 294.52(21)^{M}	0.82(16) 1.4(1) 0.62(18)	M1 + E2 M1 + E2, δ = -0.8(2) or -2.2(10)$^+$ M1 + E2	D, J	The experimental angular correlation coefficients exclude $1/2^+$ and $5/2^+$ but support $3/2^+$ spin-parity assignment.
1007.14(5)	$7/2^+$	708.52(5)^{D} 691.00(8) 548.54(5) 423.34(18)	~ 1.6 3.4(6) 1.2(2) 0.22(6)	E2 M1 + E2, δ = 0.35(5)$^+$ M1 + E2 M1 + E2	B_1, C, (D), J	New spin assigment.
1033.78(8)*	$3/2^+$	1033.80(12) 735.19(10) 449.9(3)	4.0(8) 2.7(7) 0.19(4)	M1 + M2, δ = -0.52(22)$^+$ M1 + E2 M1 + E2	J	

Level	Jπ	Depopulating transition	Intensity	Multipolarity	XREF	Comments
1037.38(5)*	$7/2^+$	738.76(9) 721.22(8) 453.44(11) 356.7(4)	2.2(6) 2.5(7) 0.36(7) 0.23(7)	E2 M1 + E2, $\delta = 0.29(1)^+$ M1 + E2 E2	C, J	
1047.53(11)	$7/2^+$	731.37[D] 588.92(16) 463.69(13)	2.8(7) 1.1(2) 0.23(4)	M1 + E2 M1 + E2 M1 + E2	B_1, J	
1049.70(9)	$3/2^+$	1049.75(16) (733.3 369.10(11)	3.1(3) ~0.6(masked) 0.55(11)	M1 + E2, $\delta = -0.49(8)$ or -30(+60, - 20) M1 + E2) M1 + E2	B_0, J, L	Intensity of the 733.3 keV transition was deduced from the equivalent data of Matumoto et al[28].
1050.85(7)*	$7/2^-$	(788.0(3) 528.78(5) 412.85(6)	0.08(2)) 1.6(3) 3.3(6)	 M1 + E2, $\delta = -2.25(115)^+$ M1 + E2, $\delta = -0.4(1)^+$	J	Jπ = $7/2^-$, $9/2^-$, $11/2^-$ are possible. Angular distribution data disfavor $9/2^-$. The strong population suggests $7/2^-$ rather $11/2^-$ spin.
1126.20(7)	$3/2^+$	1126.20(8) 827.65(25) 809.96(25) 542.4(3) 417.4(3) 242.6(3)	3.4(3) 0.40(12) 1.2(5) 0.32(6) 0.44(8) 0.04(1)	M1 + E2, $\delta = -0.02(3)$ or -1.7(1) M1 + E2 M1 + E2 M1 + E2 M1 + E2 M1 + E2	B_0, D, J, L	
1177.45 (15)	$3/2^+$	1176.76[D?]? 878.62 (9)[D] 861.24 (15)	< 1.1 $\ll 8.4$ 1.5 (2)		C, J	

Level	Jπ	Depopulating transition	Intensity	Multipolarity	XREF	Comments
1194.37(7)	3/2⁻	1194.43(10) 896.71[D] 878.62[D] 672.25(15)[D] 611.0 (3) 339.30(10)	1.08(11) ~ 0.2 ~ 0.2 2.4(6) 0.34(4) 1.6(3)	E1 E1 E1 E2 E1 M1 + E2, δ = -0.20(5)⁺	B_0, J, L	Photoactivation level. The intensities in the case of the doublets are estimated by considering the corresponding data of Matumoto et al.[28]
(1195.3	5/2⁺	897 737 487 188			B_1, D)	
1209.31(17)*	13/2⁻	945.96(15) (339.6	1.1(2) ~0.1	M1 + E2 M1 + E2)	J	
1214.23(12)*	11/2⁺	755.67(16) 274.67(18)	1.4(3) 0.14(4)	E2 M1 + E2	J	
1268.15(7)*	3/2⁺	1268.32(15) 969.55(10) 951.95(10) 684.10(11)[M]	0.44(6) 1.1(2) 1.5(3) 0.72(15)	M1 + E2 M1 + E2 M1 + E2, δ = -0.8(3)⁺ M1 + E2	J	
1279.7(2) ?	3/2⁺	1279.81(11) 980.94(25) 963.25(15) 598.88[D] 291.54(25)	0.09(2) 0.14(5) 0.16(5) ≪6.0 0.10(3)	M1 + E2 M1 + E2 M1 + E2 M1 + E2 M1 + E2	D, J	

Level	Jπ	Depopulating transition	Intensity	Multipolarity	XREF	Comments
1301.03(7)*	3/2⁺, 5/2⁺	1301.07(10) 717.13(11) 417.4(3)[M] 174.79(9)	0.41(8) 1.6(3) 0.44(8) 0.25(8)		J	
1313.73 (11)	5/2⁺	(997.58 (14) 855.05(19) (729.9)	0.25 (5) 0.08 (3)		C, J	The 729.9 keV transition was observed by Kröll and Elze[30].
1321.95(17)*	7/2⁻	1058.48(11) 799.9(6) 684.10(11)[M]	0.70(19) 0.68(3) 0.72(15)		D, J	
1351.50(9)*	5/2, 7/2	(1052.95(12)[M] 892.86(25) 829.36(25) 767.65(13) 643.14[D] 496.8(3) 344.31(12)	0.47(14)) 0.09(3) 0.73(25) 1.2(2) <0.14(3) 0.26(8) 0.08(2)		J	
1364.7 ?		(1364.7 ?) 1066.16(8) (906.08(25) 780.81(11)	 1.4(2) 0.24(2) 0.51(16)		J	
1387.44(8)*	5/2⁺, 3/2⁺	1387.3(5) 1088.89(9) 928.77(18) (678.9	0.17(8) 1.3(3) 1.0(3) covered)		(D?), J	

Level	Jπ	Depopulating transition	Intensity	Multipolarity	XREF	Comments
1390.55(9)*	1/2$^+$, 3/2$^+$	1390.42(15) 1092.18(21) 402.19(13) 356.7(4)^{D} 264.2(4)	1.4(4) 0.16(8) 0.25(7) <0.23(7) 0.14(4)		(D), J	
1405.84(9)*	1/2$^+$, 3/2$^+$	1405.85(11) 1107.11(18) 417.4(3)^{M} 279.80(15)^{M}	0.95(19) 1.1(3) 0.44(8) 0.12(2)		J	Corresponds to the 1472.7 keV level of ^{111}Cd.
1407.4(3)*	(9/2)$^+$	948.85(25) 823.64$^{D?}$	0.11(5) 1.5(3)		J	Probably corresponds to the 1552.0 keV level of ^{111}Cd.
1423.47(14)*	11/2$^-$	1160.12(11) 553.9(3)^{M}	0.64(19) 0.38(11)	M1 + E2 E2	J	Corresponds to the 1565.5 keV level of ^{111}Cd.
(1430	3/2$^+$				D)	The level was observed in (d, p) reaction with L = 2 by Goldman et al.[31]
1451.0 (2)		770.42 (16) 553.9 (3)^{M} 417.4 (3)^{M} 171.07 (12)	0.59 (18) 0.38 (11) 0.44 (8) 0.27 (8)		C, J	
1479.22(12)	1/2$^-$, 3/2	1479.19(15) 1180.70(18) (624.2 445.20^{D}	1.2(2) 0.56(11) ~0.2 masked) < 0.18(4)		B_0, (D?), J, L	The 624.2 keV transition was observed in the β-decay experiment of Matumoto et al[28]. Photactivation level.
1492.98(10)*	1/2$^+$, 3/2$^+$	1492.88(25)^{M} 1176.76(15) (1034.4 ? 909.12(13) 812.7(4) 784.6(3) 224.69(25)	0.06(2) 1.1(3) covered) 0.36(12) 0.13(6) 0.11(4) 0.03(1)		D, J	

Level	Jπ	Depopulating transition	Intensity	Multipolarity	XREF	Comments
1542.29(6)*	(1/2)$^+$	658.66(8) 539.39(22) 416.11(4)	0.68(25) 0.53(10) 0.31(4)		B_0, D, J	
1575.3(3)*	7/2$^-$	1312.18(15) 1052.95(12) 937.2(3)	0.13(3) 0.47(14) 0.24(7)		D, J	Correspond to the 1580 keV level observed in (d, p) reactions with L = 3 ? by Goldman et al[31] Possible transitions to the first 5/2$^-$ and 3/2$^-$ states are covered.
1605.72(26)* ?	(7/2 - 11/2)$^+$	1147.2(4) 665.98(25)	0.35(14) 0.79(15)		J	The level may correspond to the 1665.9 keV one in ^{111}Cd.
1607.17(9)*	5/2$^+$	1606.96(22) 1308.70(11) 1023.00(25) 926.6(4)	0.08(2) 0.34(8) 0.60(24) 0.29(12)	E2 M1 + E2 M1 + E2 M1 + E2	D, J	
1675.11(9)*	3/2$^+$	1376.64(25) 994.53(11) 791.49(15)	0.28(11) 0.40(8) 0.42(12)	M1 + E2 M1 + E2 M1 + E2	D, J	
1745.9(2)*	3/2$^-$	1746.0(5) 1429.9(4) 890.84(22) 551.50(21)$^{D?}$	0.26(9) 0.13(4) 0.16(5) (<)1.3(3)		J	Photoactivation level. One cannot exclude 1/2$^-$ or 3/2$^+$ spin assignment
1778.7(2)*	9/2$^-$	1515.4(2) 569.3(3)	0.82(16) 0.17(4)	M1 + E2 E2	J	
1798.8(2)*	(1/2- 5/2)$^+$	1798.65(25) 1482.85(25) 1214.78^D 765.1(3)	0.05(1) 0.16(5) $\leqslant$1.4 0.20(8)		(D), J	
1842.54(14)*	(3/2$^-$)	1320.43(15) (987.5 ? 648.26(25)	0.47(8) covered) 0.41(16)		D, J	The level may correspond to the 1840 keV one observed in (d, p) reaction[31] with L = 1 or 2.

Level	Jπ	Depopulating transition	Intensity	Multipolarity	XREF	Comments
1867.67(13)*	$7/2^-$, $9/2^-$	1604.23(23) 1345.56(8) 1012.91(21)	0.12(3) 0.71(5) 0.52(16)		J	
1892.09(12)*	$7/2^-$	1628.8(4) 1370.22(15) 1036.87(15)	0.23(6) 0.61(6) 0.90(27)	E2 M1 + E2 M1 + E2	G, J	Corresponds to the level observed in (p, p') reaction[22] with L = 3.
1904.27(9)*	$5/2^+$, $7/2^+$	1445.70(11) 1320.43(15) 856.73(25) 496.8(3)	1.2(2) 0.47(8) 0.08(3) 0.26(8)		J	
2037.7(2)*	5/2 - 9/2	1579.1(5) 1221.3(4) 1097.89(22)	0.12(4) 0.75(6) 0.52(19)		D, J	The level may correspond to the 2040 keV one seen by Goldman et al[31] with L = 3 and the 2050 keV one observed by Rosner[19] with L = 2. If so, the level has $7/2^-$ or $5/2^+$ spin. If not, $7/2^+$, $9/2^+$ spins are also possible.
2093.9(5)*	$7/2^-$	1830.7(5) 670.4(4)	0.17(5) 0.37(15)	E2 E2	J	
2112.8(3)*	$7/2^-$	1590.8(3) 1474.8(3)	0.35(9) 0.2(1)	M1 + E2 M1 + E2	D, J	
2173.54(12)*	$1/2^-$, $3/2^-$	2173.64(21) 1492.88(25) 1289.4(3) 979.08(23) 427.68(16)	0.34(6) 0.06(2) 0.20(5) 0.13(5) 0.26(5)	E1 E1 E1 M1 + E2 M1 + E2	D, J	Corresponds to the 2170 keV level observed in (d, p) reaction[31] with L = 1. Photoactivation level.
2319.34(19)*	$3/2^-$	2319.7(6) 1464.32(18)	0.54(22) 0.12(3)	E1 M1 + E2	D, J	Corresponds to the 2310 keV level observed in (d, p) reaction [31] with L = 1. Photoactivation level.
2759.41(15)*	$3/2^+$, $5/2^+$	2460.6(2) 1942.71(25) 1394.7(4) 960.46(15)	0.55(11) 0.27(8) 0.37(14) 0.07(2)		D, J	Corresponds to the 2750 keV level observed in (d, p) reaction [19, 31].

Table III.

Mass number	109	111	113	115	117	119
Transition energy (keV)	1386.9	435.06	258.72	212.8	157.1	81.7
Weisskopf-estimated half-life (ns)	0.00267	0.86	11.3	29.3	130	3350
Experimental	–	0.042(4)[A]	0.326(13)[B]	0.75(3)[C]	4.7(4)[D]	210(18)[E]
Enhancement	20[F]	21[A]	35	39	28	16
Experimental B(E2) (e^2b^2)	–	–	0.158(7)[G]	0.183(8)[G]	0.13(1)	0.074(6)
Calculated	0.003[H]	0.092(8)	0.147(13)	0.165(14)	0.13(1)[H]	0.074(6)[H]

Table IV.

γ-Source	Activation level energy (MeV)	Cross section (10^{-26} cm^2eV)	Reference
linac	1.12±0.01	0.01(+5,-2)	4
linac	1.19±0.1	9.8±2.5	6
linac	1.33±0.01	8(+4,-0.5)	4
^{60}Co		15±3	39
^{60}Co		10.2±2.6	40
^{60}Co		8	41
^{60}Co		11±2	42
^{60}Co		14±1	43