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Coulomb excitation of cadmium isotopes with protons

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Low-lying positive parity levels of the isotopes in natural cadmium were Coulomb excited with 2.7—4.2 MeV protons. Eight levels of ^{111}Cd up to 1130.4 keV and four levels of ^{113}Cd up to 680.5 keV excitation energy, and the first 2^+ states in even-even isotopes (^{110,112,114,116}Cd) were excited. A 50 cm^3 Ge(Li) detector was used to measure the deexcitation gamma-ray yields. The 1130.4 keV level in ^{111}Cd had not been investigated earlier through Coulomb excitation. Also the 245.4, 700, 754.9, 855.6, and 1020.7 keV levels in ^{111}Cd, and the 316.1 keV level in ^{113}Cd were Coulomb excited with protons for the first time. The reduced $E2$ transition probabilities $B(E2)$, and partial half-lives $T_{1/2}$ $(E2)$, for various levels were determined. The gamma-ray angular distributions were analyzed to deduce the $E2/M1$ mixing ratios (δ) for various transitions from the levels in ^{111,113}Cd. The 700, 754.9, 855.6, and 1020.7 keV levels in ^{111}Cd, and the 680.5 keV level in ^{113}Cd have been assigned a spin value of $\frac{3}{2}^+$, while the 1130.4 keV level in ^{111}Cd has been assigned a spin of $\frac{5}{2}^+$. The results have been compared with existing theoretical and experimental data in the literature.

I. INTRODUCTION

The investigations of the low-lying energy levels of cadmium isotopes have been carried out theoretically as well as experimentally by many workers. The even-even isotopes follow the well-known pattern of vibrational states. The levels of even-odd isotopes of ^{111,113}Cd, however, have been suggested mostly to be the members of the multiplet which results from the weak coupling of the 63rd and 65th odd neutrons, respectively, to the excited states of an even-even core. Our special interest in making these measurements was to Coulomb excite the levels in even-odd isotopes which have the ground state configuration $(3S_{1/2})^1_n$. Theoretically, calculations have been performed on the basis of pairing-plus-quadrupole interaction,[1,2] to predict the reduced quadrupole transition probabilities for the two low-lying levels in ^{111}Cd and two in ^{113}Cd. In the case of ^{113}Cd, the calculations for the three low-lying levels have also been performed with the distorted-wave Born approximation (DWBA).[3]

Earlier the experimental studies of these isotopes were carried out by various methods, i.e., radioactive decay;[4-12] stripping and pickup reactions;[13,14] and inelastic scattering[3,4] and Coulomb excitation with protons,[15,16] alphas,[8] and heavy ions[17,18] like ^{12}C and ^{14}N ions.

McDonald and Porter[8] have reported $B(E2)$ values for four levels of ^{111}Cd up to 755.6 keV, while Galperin *et al.*[17] excited seven levels up to 1020.7 keV excitation energy. The latter group used a relatively small size (3 cm^3) Ge(Li) detector. Also, earlier work had not properly taken into account the feeding of levels through cascade transitions. In some cases, the corresponding results of these two groups differ significantly with each other as well as with the theoretical predictions.[1-3,8] The earlier Coulomb excitation study[15] of ^{111}Cd with protons, performed with a low energy resolution spectrometer, however, could resolve only two levels at 342.1 and 620.2 keV excitation energies.

Many workers have carried out investigations of levels of ^{113}Cd using Coulomb excitation with protons[15,16] and heavy ions.[18] The reduced quadrupole transition probabilities have been studied for 298.4, 316.1, 583.9, and 680.5 keV states by Andreev *et al.*[18] But, angular distribution studies[15] have been carried out only for two states at 298.4 and 583.9 keV. Investigations of the electromagnetic properties of even-even cadmium isotopes through Coulomb excitation have been carried out by several workers.[19-26] The study of the properties of the first 2^+ excited states of these nuclei provides a good check on our method of investigation.

It was, therefore, considered worthwhile to carry out the Coulomb excitation studies of cadmium nuclei with low energy protons by using a high resolution Ge(Li) detector. The possibility of multiple Coulomb excitation with protons is negligible; hence the reduced quadrupole transition probabilities of excited states and the mixing ratios of the transitions can be extracted unambiguously.

Eight levels up to 1130.4 keV excitation energy in ^{111}Cd and four levels up to 680.5 keV in ^{113}Cd were populated in the present work. In even-even isotopes of ^{110,112,114,116}Cd, only the first 2^+ level could be excited. The prevailing mode of reaction mechanism was ascertained to be Coulomb excitation, through agreement between the theoretical and experimental excitation functions over the energy range used in the experiment. The 1130.4 keV level in ^{111}Cd was populated through Coulomb excitation for the first time. The reduced transition probabilities, $B(E2)$ values, and partial half-lives for decay of these levels were extracted. The angular distribution data were analyzed to extract the angular distribution parameters A_2 and the mixing ratios (δ) for the various transitions involved, and to assign the definite spin values out of the possible values of $\frac{3}{2}^+$ and $\frac{5}{2}^+$.

II. EXPERIMENTAL PROCEDURE

Coulomb excitation was effected with protons accelerated by the Variable Energy Cyclotron at Panjab University, Chandigarh.[34,35] The energy resolution of the beam was about 30 keV. The target, a thick foil of 99.9% spectroscopically pure natural cadmium, was mounted at an inclination of 45° to the beam direction at the center of a cylindrical scattering chamber of brass, having 7.2 cm inner diameter and 1.5 mm thick walls. The well focused and collimated beam bombarded the target on a spot of about 4 mm diameter.

The deexcited gamma rays were detected at a distance of about 8.8 cm from the target, with a 50 cm^3 Ortec Ge(Li) detector having an energy resolution of about 2.0 keV for the 1.332 MeV gamma ray from the ^{60}Co source. The spectrum was recorded on a 4096-channel analyzer (ND 100). The details of charge integration and absolute photopeak efficiency of the Ge(Li) detector are the same as given in our previous paper.[37]

The proton beam energy was varied in large energy steps from 2.7 to 4.2 MeV, and the gamma-ray measurements were performed for each incident energy at 55° to the beam direction to eliminate the anisotropy effects. The background gamma-ray yields were measured with beam off and on, with the target replaced with a carbon foil. With a 4.0 MeV proton beam, the measurements were also carried out at 0° and 90° to the beam direction to provide data for the anisotropy treatment. The beam current was maintained around 150 nA to avoid pileup in the electronic circuit and to minimize the dead-time correction for the multichannel analyzer.

III. EXPERIMENTAL RESULTS AND ANALYSIS

A. Gamma ray yields

The peaks observed in the gamma ray spectra obtained at various incident proton energies were assigned to the transitions from the known levels in ^{111}Cd, ^{113}Cd, and various even-even Cd isotopes, and also to the background. A specimen gamma-ray spectrum displaying the well-resolved peaks marked with the sources of origin, recorded with 3.7 MeV incident protons, is shown in Fig. 1. Thirteen gamma-ray peaks, as shown in Fig. 2, were assigned to the transitions from the deexcitation of levels in ^{111}Cd, six to ^{113}Cd (Fig. 3), and one to each of the even-even isotopes ^{110,112,114,116}Cd. The remaining gamma-ray peaks owed their origin to the background.

The experimental thick-target gamma-ray yield per incident proton (Y) was extracted for each transition from the number of counts (N) in the corresponding gamma-ray peak obtained with the computer code SAMPO (Ref. 33) and q, the charge (in Coulomb) incident on the target during the run of the experiment, through the expression

$$Y=\frac{1.602\times10^{-19}}{fq}\left[\frac{(1+\alpha_T)N}{\overline{W}(\theta)\epsilon_\gamma}-T_c\right], \tag{1}$$

where the division by fractional abundance f of the isotope concerned in natural cadmium converts the observed gamma-ray yield to the one from the 100% enriched isotope. The absolute detector efficiency ϵ_γ for the experimental geometry also takes into account the absorption of gamma-ray intensity in the wall of the target chamber as

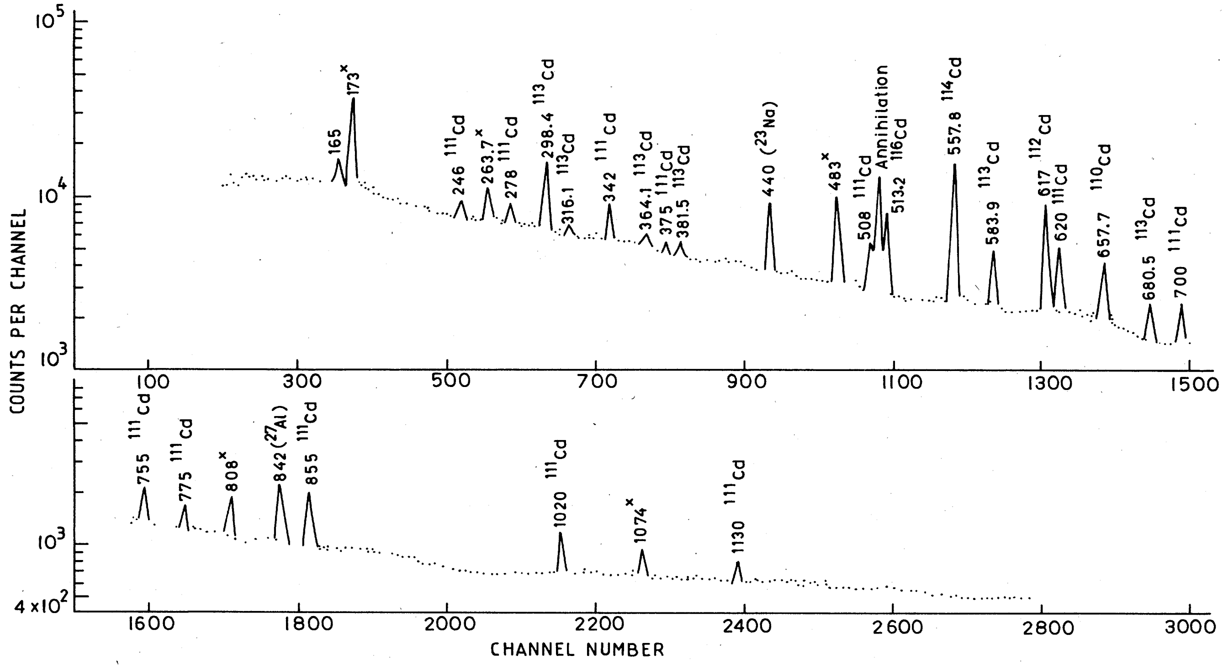

FIG. 1. Gamma-ray spectrum observed with a 50 cm^3 Ge(Li) detector when 3.7 MeV protons Coulomb excited the natural cadmium. The peaks marked × correspond to background gamma rays.

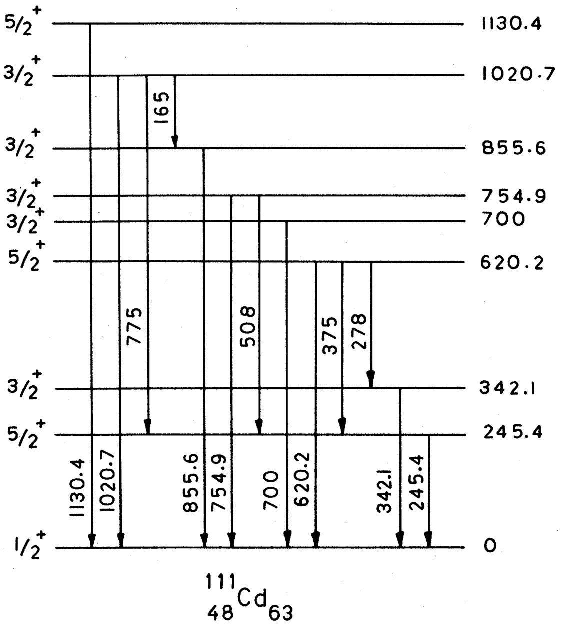

FIG. 2. Level diagram of states observed in the Coulomb excitation of ^{111}Cd.

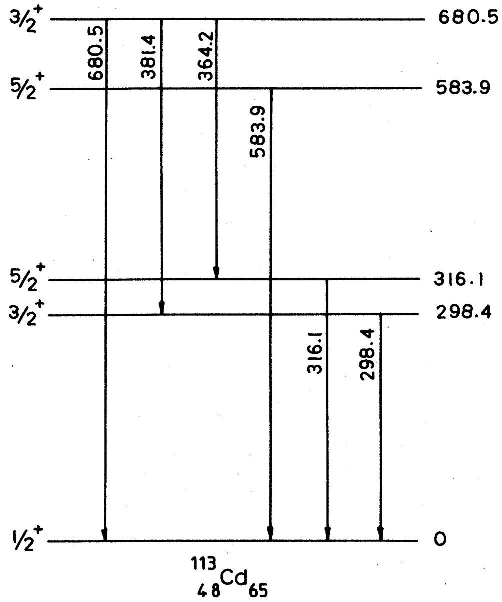

FIG. 3. Level diagram of states observed in the Coulomb excitation of ^{113}Cd.

well as in the target material. The factor T_c, which accounts for the population of the concerned level due to feeding through cascade transitions from the higher excited levels, was calculated from the data for each case. The quantity $\overline{W}(\theta)$, that takes into account the anisotropy in the gamma ray angular distribution, assumes a unity value at 55° to the beam direction.

The values of $B(E2)$ were obtained from gamma-ray yields per incident particle Y at 55° from the expression

$$Y=\epsilon B(E2)\uparrow\left[\frac{4.819\times10^{-19}Na}{A}\left[\frac{A_2}{A_1+A_2}\right]^2\frac{A_1}{Z_2^2}\times\int_0^{E_{\max}}(E-\Delta E')f_{E2}(\eta_i,\xi)\frac{dE}{dE/dX}\right]\times10^{-24}. \qquad (2)$$

The various symbols in Eq. (2) carry the usual meaning as

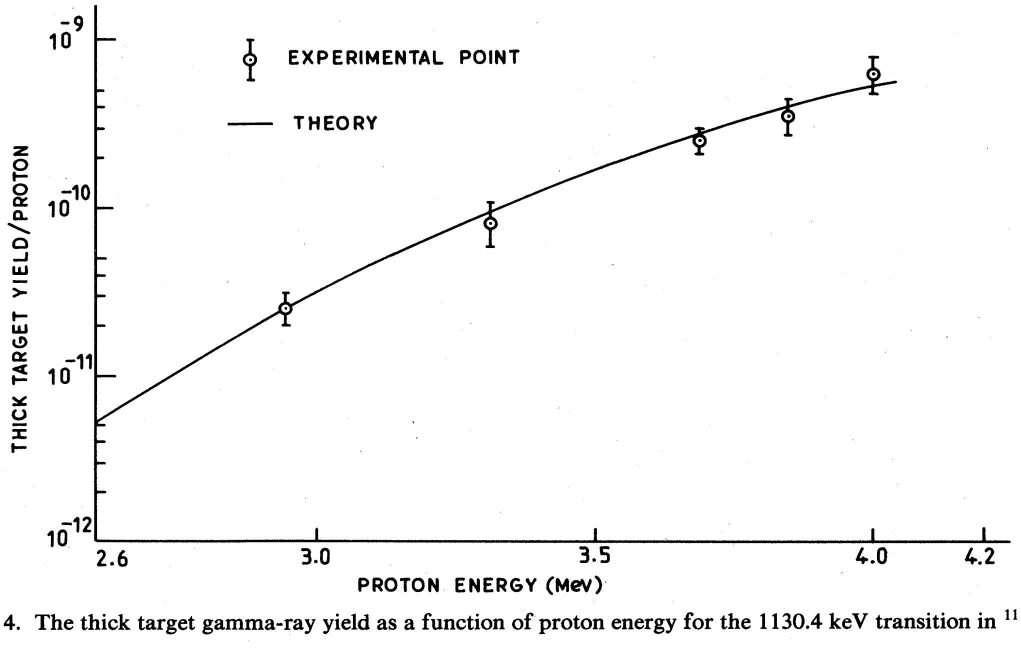

FIG. 4. The thick target gamma-ray yield as a function of proton energy for the 1130.4 keV transition in ^{111}Cd.

TABLE I. $B(E2)\uparrow$ values of the first 2^+ states of even-even cadmium nuclei. $b^2=10^{-48}$ cm^4.

Even-even Cd isotopes	Level energy (keV)	Measured $B(E2)\uparrow$ (e^2b^2)			
		Milner (Ref. 21)	Steadman (Ref. 22)	Esat (Ref. 26)	Present work
110	657.7	0.467±0.019	0.436±0.022	0.432±0.006	0.415±0.006
112	617.4	0.524±0.021	0.478±0.033	0.484±0.004	0.486±0.005
114	557.8	0.576±0.023	0.560	0.528±0.004	0.574±0.018
116	513.1	0.581±0.023	0.653±0.035		0.608±0.030

described by Alder *et al.*[27] The branching ratios for the various observed transitions from the concerned excited state and the corresponding total conversion coefficients were obtained from the literature.[8,12,17,30–32] These quantities were required to define the decay fraction ϵ for the detected gamma rays. The factors $f_{E2}(\eta_i,\xi)$ were obtained by interpolation of the values tabulated by Alder *et al.*[27] We used Bethe's formula for the stopping power of cadmium for protons. The calculations for $B(E2)$ were carried out with a DEC20 computer, evaluating the integral numerically.

The contribution to the observed gamma-ray yields arising due to compound nucleus formation was computed theoretically using the code CINDY (Ref. 28) and was found to be less than one percent of the yield due to the Coulomb excitation process. The direct reaction effects at these low energies have negligible contributions and were not considered.

The excitation functions were obtained at various incident proton energies and it was found that only the Coulomb field was responsible for $E2$ excitation of all levels in different cadmium isotopes. A specimen case of the 1130.4 keV transition is shown in Fig. 4. This curve has been compared with the predictions of the first order perturbation theory[27] for $E2$ excitation which confirmed the Coulomb character of the 1130.4 keV level.

The assigned errors in the $B(E2)$ values result mainly from the errors in the peak area, the calibrated efficiency of the Ge(Li) detector, and the stopping power for protons in cadmium. The beam energy resolution and uncertainty effects produce relatively insignificant errors. The experimentally determined values of $B(E2)$ along with their comparison with earlier results for ^{110,112,114,116}Cd and ^{111,113}Cd are shown in Tables I and II, respectively.

B. Angular distributions

For Coulomb excitation studies, the angular distributions of the deexcitation gamma rays were taken to be of the form

$$W(\theta)=1+a_2g_2A_2P_2(\cos\theta)+a_4g_4A_4P_4(\cos\theta)\ , \qquad (3)$$

where a_2 and a_4 are the thick-target particle parameters,[27] g_2 and g_4 are the finite angular resolution correction factors, and $P_2(\cos\theta)$ and $P_4(\cos\theta)$ are the Legendre polynomials. The angular distribution coefficients A_2 and A_4 are quantities which, for Coulomb excitation, can be calculated exactly. They are the functions of spin sequence and the $E2/M1$ gamma-ray mixing ratio. The term $a_4g_4A_4p_4(\cos\theta)$ in Eq. (3) has been neglected since a_4 is very small. Because of this fact, the measurement of $R=W(0°)/W(90°)$ determines A_2 and hence the spin

TABLE II. $B(E2)\uparrow$ values of the levels of ^{111,113}Cd.

Level energy (KeV)	$B(E2)\uparrow$ (e^2cm$^4\times10^{-50}$)				
	Present work	Galperin (Ref. 17)	McDonald (Ref. 8)	McGowan (Ref. 6)	Andreev (Ref. 18)
			^{111}Cd		
245.4	0.28±0.02	1.60±0.40	0.23±0.05		
342.1	9.77±0.52	11.0 ±2.0	8.7 ±1.0	11.0±0.9	
620.2	13.34±1.08	14.0 ±3.0	12.6 ±1.7	14.3±2.2	
700	0.66±0.17	0.3 ±0.1			
754.9	2.74±0.80	2.2 ±0.7	4.2 ±0.8		
855.6	0.37±0.14	0.07±0.03			
1020.7	3.08±0.90	2.4 ±1.1			
1130.4	0.92±0.19				
			^{113}Cd		
298.4	14.06±1.06			11.0±0.9	13.0±2.0
316.1	0.63±0.06				0.8±0.1
583.9	28.9 ±2.1			30.4±3.3	32.0±6.0
680.5	9.96±0.73			9.0±1.4	7.0±1.5

sequence(s) and mixing ratios allowed for a particular transition. As the angular distribution of the $2_1^+ \rightarrow 0_1^+$, 557.8 keV transition in ^{114}Cd is unique, this angular distribution was also used to normalize the data.

To assign definite spin values to some of the excited levels, we have exploited the fact that the value of the coefficient A_2 should be around +0.286 for the $\frac{5}{2}^+ \rightarrow \frac{1}{2}^+$ transition. On the other hand, for the $\frac{3}{2}^+ \rightarrow \frac{1}{2}^+$ transition, the value of A_2 should be significantly less. To further confirm the spin assignments, we subjected the data to a χ^2 test as described in our earlier work.[37] Three typical plots for the 700, 855.6, and 1020.7 keV transitions are displayed in Fig. 5. The spin values corresponding to the curves with minima lying below the χ^2 value at the 0.1% level of significance for a case of 2 degrees of freedom were considered acceptable. The results obtained from the present angular distribution measurements are shown in Table III.

On the basis of this analysis, the 700, 754.9, 855.6, and 1020.7 keV levels in ^{111}Cd and the 680.5 keV level in ^{113}Cd have been assigned a $\frac{3}{2}^+$ spin, while the 1130.4 keV level in ^{111}Cd and the 316.1 and 583.9 keV levels in ^{113}Cd were assigned a $\frac{5}{2}^+$ spin. In cases where lifetimes of the states are not available in the literature, we could not decide between two possible values for the δ parameter, defined according to the convention, for a given spin sequence, and could assign only tentative values of δ. The errors in δ values were estimated from the uncertainties in the A_2 coefficients propagated from the measured gamma-ray yields.

IV. DISCUSSION OF LEVEL PROPERTIES

A. Even-odd isotopes

The observed decay schemes of the Coulomb excited levels in ^{111}Cd and ^{113}Cd isotopes are shown in Figs. 2 and 3, respectively. All the known levels with spins and parities restricted either to $\frac{3}{2}^+$ or $\frac{5}{2}^+$ were excited. The excitation of the 1020.7 keV level in ^{111}Cd through the $E2$ mode of Coulomb excitation in the present experiment suggests that its spin-parity value should also be confined to either of these two values rather than to $\frac{1}{2}^+$. The summary of the level properties of ^{111}Cd and ^{113}Cd are presented in Tables IV and V, respectively. The comparison of experimental $B(E2)\uparrow$ values with the theory for the levels of ^{111}Cd is given in Table VI. A brief discussion of the results of the levels in ^{111,113}Cd follows.

B. Levels in ^{111}Cd

1. The 245.4, 342.1, and 620.2 keV levels

The present values of $B(E2)$, the spin assignments, and the δ values (Tables II and III) agree, in general, with the literature[8,15,17] within experimental errors, except that the value of $B(E2)$ for 245.4 keV, as reported by Galperin *et al.*,[17] is about six times higher than our value. Perhaps the small size of the detector with low resolution used by Galperin *et al.*[17] might have resulted in the higher value of $B(E2)$ with large uncertainties.

While our value of $B(E2)\downarrow/B(E2)_{\text{s.p.}}$ for the 245.4 keV

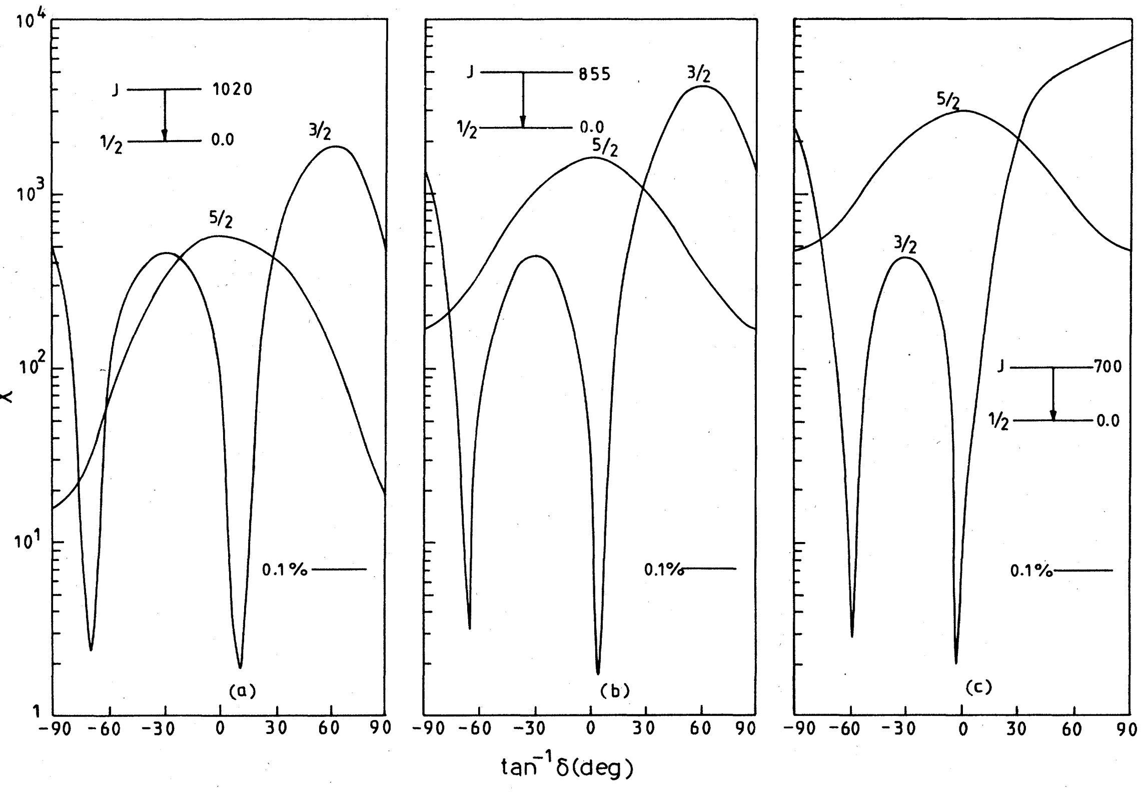

FIG. 5. Values of χ^2 as a function of mixing ratio for (a) 1020.7 keV, (b) 855.6 keV, and (c) 700 keV transitions.

TABLE III. Summary of gamma-ray anisotropy results from the Coulomb excitation of ^{111,113}Cd.

E_γ (keV)	$R=\dfrac{W(0°)}{W(90°)}$	a_2	A_2[a]	$\delta=(E2/M1)^{1/2}$ Present	Previous
			^{111}Cd		
245.4	1.172±0.058	0.394	0.289±0.092		
342.1	1.060±0.033	0.522	0.080±0.043	0.36 ±0.05	0.39±0.03[b]
620.2	1.332±0.071	0.766	0.274±0.053		
700	0.751±0.014	0.813	−0.234±0.013	0.018±0.014 or −1.81±0.07	
754.9	0.824±0.022	0.844	−0.152±0.020	0.11±0.04 or −2.26±0.16	
855.6	0.798±0.018	0.886	−0.171±0.016	0.087±0.018 or −2.14±0.10	
1020.7	0.921±0.022	0.949	−0.06 ±0.02	0.21±0.02 or −3.00±0.17	
1130.4	1.474±0.026	0.992	0.284±0.014		
			^{113}Cd		
298.4	1.014±0.07	0.472	0.021±0.009	0.29 ±0.01	0.29±0.011[b]
316.1	1.202±0.011	0.493	0.270±0.014		
364.2	0.754±0.030	0.802	−0.234±0.031	−0.035±0.030	
381.5	0.866±0.078	0.802	−0.123±0.075	0.19 ±0.09	
583.9	1.261±0.015	0.743	0.226±0.012		
680.5	0.719±0.013	0.802	−0.268±0.014	−0.022±0.016	

[a] Values obtained using $W(\theta)=1+a_2g_2A_2P_2(\cos\theta)$; a_2 is the thick target particle parameter and g_2 is the finite solid angle correction.
[b] Reference 15.

level is in agreement with the theoretical predictions of Ikagami and Udagawa,[29] they do not agree with the value quoted by McDonald and Porter,[8] which seems to be too large for this weakly excited state. Our angular distribution results support the earlier spin assignments of $\frac{5}{2}^+$, $\frac{3}{2}^+$, and $\frac{5}{2}^+$ for the 245.4, 342.1, and 620.2 keV levels, respectively.

2. The 700, 754.9, 855.6, and 1020.7 keV levels

The present $B(E2)$ values for the 700 and 855.6 keV levels are significantly higher than the corresponding results of Galperin *et al.*,[17] whereas in the case of the 754.9 and 1020.7 keV levels there seems to be a reasonable agreement with the corresponding earlier reported values. The $B(E2)\downarrow/B(E2)_{\text{s.p.}}$ values for these levels suggest that only the 754.9 and 1020.7 keV levels inherit some significant collective nature. As shown by the χ^2 test, as presented in Fig. 5, each of these levels has been assigned a definite spin value of $\frac{3}{2}$. As half-life measurements for these states are not available in the literature, we could not decide definitely the appropriate value of the δ parameter out of the two possible values in each case. We, nevertheless, have tentatively assigned δ values to these levels, keeping in view the order of our $T_{1/2}$ $(E2)$ values for these levels.

3. The 1130.4 keV level

This level has been reported earlier only in stripping and pickup reaction studies.[13] As discussed in Sec. III A, the resemblance of the theoretical and experimental exci-

TABLE IV. Summary of the level properties of ^{111}Cd.

Level energy (keV)	J^π	$B(E2)\downarrow$ (e^2cm^4$\times10^{-50}$)	$T_{1/2}(E2)$ (ps) Present work	McDonald and Porter (Ref. 8)	Galperin *et al.* (Ref. 17)
245.4	$\frac{5}{2}^+$	0.092±0.007	72 ±5×10^3	90.5×10^3	11.8×10^3
342.1	$\frac{3}{2}^+$	4.88 ±0.26	247 ±21	278	215
620.2	$\frac{5}{2}^+$	4.45 ±0.36	14.3± 1.1	14.8	13.2
700	$\frac{3}{2}^+$	0.33 ±0.09	102 ±26		(228–339)
754.9	$\frac{3}{2}^+$	1.37 ±0.40	16.8± 5.0	16.4	(20.8–31.9)
855.6	$\frac{3}{2}^+$	0.19 ±0.07	94 ±35		(353–534)
1020.7	$\frac{3}{2}^+$	1.54 ±0.45	3.3± 1.0		(4.3–6.4)
1130.4	$\frac{5}{2}^+$	0.31 ±0.06	>10		

TABLE V. Summary of the level properties of ^{113}Cd.

Level energy (keV)	J^{π}	E_{γ} (keV)	$B(E2)\downarrow$ (e^2cm$^4\times10^{-50}$)	$\frac{B(E2)\downarrow}{B(E2)_{\text{s.p.}}}$	$\frac{B(M1)\times10^2}{(e\hbar/2MC)^2}$	$T_{1/2}$
298.4	$\frac{3}{2}^+$	298.4	7.03±0.53	21.7 ±1.6	5.3 ±0.5	28.0±2.2 ps
316.1	$\frac{5}{2}^+$	316.1	0.21±0.02	0.65±0.06		6.9±0.6 ns
583.9	$\frac{5}{2}^+$	583.9	9.63±0.70	29.7 ±2.2		9.0±0.7 ps
680.5	$\frac{3}{2}^+$	680.5	4.98±0.37	14.34±1.14	0.60±0.06	6.1±0.5 ps
		381.5	0.7 ±0.3	2.2 ±0.9	2.0 ±0.9	
		364.2	0.03±0.02	0.10±0.06	2.4 ±1.6	

tation functions for the observed ground state transition confirmed the direct $E2$ mode of excitation for this level. From the value of $B(E2)\downarrow/B(E2)_{\text{s.p.}}$ we confirm that this level has a weak collective component. The 0.284±0.014 value for the coefficient A_2 suggests a spin value of $\frac{5}{2}^+$ for this level. The reduced $E2$ transition probability $B(E2)\downarrow$, and the half-life $T_{1/2}$ for this level were extracted to be 0.31±0.06 (e^2cm$^4\times10^{-50}$) and > 10 ps, respectively, considering only a single transition from the level at 1130.4 keV (Table IV).

C. Levels in ^{113}Cd

$B(E2)$ values for the ground state transitions from the four excited levels at 298.4, 316.1, 583.9, and 680.5 keV excitation energies are in agreement with the previously reported results. The 316.1 and 689.4 keV levels reported by Andreev *et al.*[18] were not observed by McGowan and Stelson.[15] The 689.4 keV level was also not excited in the present experiment.

The results of analysis of the angular distribution data are in agreement with the earlier assignment of $\frac{3}{2}^+$ and $\frac{5}{2}^+$ spin values, respectively, for the 298.4 and 583.9 keV levels. The 316.1 and 680.5 keV levels have been tentatively assigned $\frac{5}{2}^+$ and $\frac{3}{2}^+$ spin, respectively, in previous experimental studies, through β decay[10,11] and stripping reactions.[14] From our analysis, we have now unambiguously assigned $\frac{5}{2}^+$ and $\frac{3}{2}^+$ spins to these levels, respectively. The present mixing ratio for the 298.4 keV transition agrees with the value quoted by McGowan and Stelson.[15] For other ground state transitions, as well as for 364.2 and 381.5 keV intermediate transitions from the 680.5 keV level, no angular distribution results are available in the literature.

The enhancement factor over the corresponding single particle transition probabilities suggests that the 298.4, 583.9, and 680.5 keV levels inherit a predominant collective nature, whereas the 316.1 keV level seems to have an important contribution from the single particle excitation. These results of 298.4, 583.9, and 680.5 keV levels are in qualitative agreement with the theoretical calculations based on the pairing-plus-quadrupole force model[1,2] as well as with the experimental results of direct reaction studies.[3] For the 316.1 keV level, however, neither theoretical nor experimental results have been reported in the literature. Our $T_{1/2}$ $(E2+M1)$ values for the four levels excited are in reasonable agreement with the corresponding results reported in the literature.[15,18,31]

V. CONCLUSION

Out of the eight energy levels excited in ^{111}Cd, and the four levels in ^{113}Cd, new information about $B(E2)$ has been obtained for the 1130.4 keV level in ^{111}Cd, and definite spin values have been assigned to the 700, 754.9, 855.6,

TABLE VI. Comparison of experimental $B(E2)\downarrow$ values with the theory for the levels of ^{111}Cd.

		$B(E2)\downarrow/B(E2)_{\text{s.p.}}$			
			Theory		
Level (keV)	Assumed spin	Experimental (Present work)	Koike (Ref. 3)	McDonald and Porter (Ref. 8)	Reehal and Sorensen (Ref. 2)
245.4	$\frac{5}{2}$	0.29±0.02	0.28[a]	6.84	
342.1	$\frac{3}{2}$	15.42±0.82	15	10.6	33.2
620.2	$\frac{5}{2}$	14.03±1.14	15	12.0	3.6
700	$\frac{3}{2}$	1.04±0.27			
754.9	$\frac{3}{2}$	4.3 ±1.3			
855.6	$\frac{3}{2}$	0.60±0.22			
1020.7	$\frac{3}{2}$	4.8 ±1.4			
1130.4	$\frac{5}{2}$	1.0 ±0.2			

[a] Ikegami and Udagawa (Ref. 29).

1020.7, and 1130.4 keV levels in ^{111}Cd and the 680.5 keV level in ^{113}Cd. Further angular distribution coefficients A_2 and the mixing ratios have been obtained unambiguously for the first time for the gound state transitions from levels at 316.1, 583.9, and 680.5 keV energy, and for some intermediate transitions. In some cases, like the 700, 754.9, 855.6, and 1020.7 keV transitions, however, we could assign only tentative values of the mixing ratios. In addition to these studies, the ambiguities in the values of $B(E2)$ for some of the levels have been removed.

The present measurements show that the levels at 342.1 keV ($\frac{3}{2}^+$) and 620.2 keV ($\frac{5}{2}^+$) in ^{111}Cd are strongly excited, indicating that they arise from the weak coupling of the odd particle to the excited state of an even-even core.[36] The theoretical predictions on $B(E2)$ by Koike,[3] and by McDonald and Porter[8] for these levels agree with the experimental results, but calculations of Reehal and Sorensen[2] give a greater magnitude. The smaller values of $B(E2)$ for other levels show the limitations of the core-excitation model.[36] The calculated results of Ikegami and Udagawa[29] for the 245.4 keV level in ^{111}Cd is in good agreement with the present measured $B(E2)$.

The low-lying levels of ^{113}Cd are similar to those of ^{111}Cd. In the present experiment the levels at 298.4, 583.9, and 680.5 keV are found to be collective in excitation. The theoretical predictions for $B(E2)$ values are relatively larger in magnitude for the 298.4 and 583.9 keV levels, but for the 680.5 keV level the results of Koike[3] are reasonably close to the present measured value. The level at 316.1 keV excitation energy has not been discussed theoretically, but our result on $B(E2)$ reasonably agrees with the reported value of Andreev[18] within the error bars.

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