defined by the equation

$$k\partial V_0(k)/\partial k=2\epsilon(k)\{[M/M_0^*(k)]-1\}, \quad (74)$$

where $\epsilon(k)=\hbar^2k^2/2M$. In problems, where one is interested in the real single-particle potential defined in Eq. (27), more important than the "model" effective M_0^* is the "real" effective mass M^* defined by the equation

$$k\partial U_0(k)/\partial k=k\partial[V_0(k)+V_{0R}(k)]/\partial k =2\epsilon(k)\{[M/M^*(k)]-1\}. \quad (75)$$

From Eqs. (74) and (75) one gets

$$[M/M_0^*(k)]-[M/M^*(k)] =-\tfrac{1}{2}k\epsilon(k)^{-1}\partial V_{0R}(k)/\partial k. \quad (76)$$

If we insert into Eq. (76) the numerical values given in Eqs. (70) and (71), we get $M^*(k_F)/M=0.94$ compared to the BG value of $M_0^*(k_F)/M=0.73$. This is only a rough estimate based on the approximate value of $k_F[\partial V_{0R}(m)/\partial m]_{m=k_F}$ given in Eq. (71). However, an appreciable increase in the effective-mass results from the rearrangement effects.

ACKNOWLEDGMENTS

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Decay of Cd^{117}

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The Cd^{117} activity produced by (n,γ) reaction on Cd^{116} was found to decay with a half-life of $\sim$3 h indicating that the possible isomer also has a half-life almost equal to that of the ground state. The presence of such an isomer was established by beta-gamma coincidence measurements. The highest energy beta group as studied in the intermediate image beta-ray spectrometer showed an end point of 2250 keV. The singles gamma spectrum was complex in nature and extended up to 2450 keV. Beta-gamma and gamma-gamma coincidence studies revealed 29 gamma transitions and eight beta groups belonging to the decay of both the activities of Cd^{117}. Based on these and the results of sum coincidence and total absorption studies a decay scheme with levels in In^{117} at 310, 590, 660, 750, 880, 1070, 1410, 1700, 1890, 1980, 2120, 2320, and 2450 keV has been proposed. Possible spins and parities for these levels have been discussed.

I. INTRODUCTION

THE decay of Cd^{117} was first investigated by Cork and Lawson.[1] They used (d,p) reaction on Cd and identified the Cd^{117} activity of 3.75-h half-life from its daughter In^{117}. Coryell and co-workers[2,3] ascertained the genetic relationship of Cd^{117} by milking it from 1.1-min Ag^{117} produced in the fission of uranium. They reported that the ground state of Cd^{117} decays with a half-life of 50-min and that it has an isomer with a half-life of 3-h. Gleit[4] used (n,γ) reaction on enriched Cd^{116} to produce Cd^{117}. In his study, he observed various gamma rays of energies between 90 and 2000 keV. These were ascribed to 3-h Cd^{117m} decaying to 1-h In^{117}. He has indicated that about 20% of Cd^{117m} decays to the 50-min ground state by a 440-keV isomeric transition. According to him, the 50-min ground state of Cd^{117} shows little gamma activity and it mainly decays by a beta transition of end-point energy 2300 keV to the 1.9-h isomer of In^{117}. The 1.9-h isomer of In^{117} decays[5] partly by an isomeric transition of energy 310 keV to the 1-h ground state and partly by beta emission to various energy levels of Sn^{117}. The maximum beta energy in this decay is 1770 keV. The ground state of In^{117} mainly decays by beta emission to the 726-keV level of Sn^{117}. It has been suggested[4] that the 3-h activity of Cd^{117} is the $h_{11/2}$ state and the 50-min activity of Cd^{117} is the $s_{1/2}$ ground state. The energy levels of In^{117} have not been established so far. Recently, Tang and Coryell[6] have reported that the 50-min activity of Cd^{117} is not produced appreciably by (n,γ) reaction on enriched Cd^{116}.

In the present work a systematic study has been carried out to establish the energy levels of In^{117}. Efforts have been made to search for the reported isomer of Cd^{117}.

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[1] J. M. Cork and J. L. Lawson, Phys. Rev. **56**, 291 (1939).

[2] C. D. Coryell, P. Leveque, and H. G. Richter, Phys. Rev. **89**, 903 (A) (1953).

[3] U. Schindewolf, J. M. Alexander, and C. D. Coryell, Phys. Rev. **111**, 228 (1958).

[4] C. E. Gleit, MIT Laboratory for Nuclear Science, Annual Progress Report, 1957, p. 35 (unpublished).

[5] C. L. McGinnis, Phys. Rev. **97**, 93 (1955).

[6] C. W. Tang and C. D. Coryell, MIT Laboratory for Nuclear Science, Progress Report No. NYO-10062, p. 14, 1962 (unpublished).

II. SOURCE PREPARATION

The sources of Cd^{117} were produced by irradiating 96% enriched Cd^{116}, in the form of CdO, in Apsara Reactor at Trombay. In the first series of irradiations, intended to look for the radiations from an expected shorter lived activity of Cd^{117}, the samples were irradiated only for 5 min to reduce the build up of the longer lived isomer. In this series, no chemical separation was performed, so that the study of the gamma spectra could be started within a few minutes after irradiation. The second series of irradiations were of longer duration, ranging from 1 to 8 h to get high specific activity and the samples were chemically separated as described below:

The irradiated sample was dissolved in HCl and 10 mg each of iron, zinc, and silver carriers were added. The AgCl precipitate was removed by centrifugation. Ammonium hydroxide was then added to the solution to precipitate $Fe(OH)_3$ and the precipitate was again removed by centrifugation. The supernate was saturated by H_2S whereby ZnS and CdS were precipitated. The precipitate was centrifuged and washed with distilled water and redissolved in HCl. Ten mg of $SnCl_2$ carrier solution was added and H_2S was passed through to precipitate the sulfides. The precipitate now contained sulphides of tin, zinc, and cadmium and was separated by centrifugation method. Stannous sulfide was removed by dissolving in NaOH and the ZnS and CdS were washed with distilled water. These were dissolved in $4N$ H_2SO_4 and H_2S was passed through the solution. Only CdS precipitated, leaving Zn in solution. The precipitated CdS was centrifuged off, washed with distilled water, and was dissolved in dilute HCl. This solution was evaporated to dryness and $CdCl_2$ sample was dissolved in a few drops of distilled water. The beta and gamma sources were prepared by evaporating a small fraction of this solution on a Mylar film of 400 $\mu g/cm^2$ thickness and a Perspex strip, respectively.

III. SEARCH FOR THE ISOMER OF Cd^{117}

To search for the radiations of any shorter lived isomer, a sample was irradiated for 5 min and the study of gamma spectrum started within 5 min after irradiation, using a 3-in.×3-in. NaI(Tl) crystal and a 512-channel analyzer. Initially, the spectra were recorded at intervals of 20 min and later at intervals of one hour. From the analysis of ten successive spectra it was observed that all the gamma rays, except those belonging to In^{117} (160, 310, 570, 620, and 880 keV) decay with the same half-life of 3 h. No gamma ray was found to decay with an appreciably shorter half-life. The first spectrum obtained from this 5-min irradiated sample was compared with that of a sample irradiated for 3 h and chemically purified. Both the spectra were essentially the same.

The presence of any beta activity decaying with a half-life shorter than 3 h has been investigated by studying the decay of the gross beta activity of a 5-min irradiated sample above 1770 keV, which is the highest beta energy in In^{117}. In this case no chemical separation was carried out. The counting was started in a methane flow proportional counter within 10 min after the end of irradiation. An aluminum absorber of 840 mg/cm^2 thickness was used to absorb beta particles of energy up to 1800 keV. The counts were recorded initially at 5-min intervals and later on at 10- to 15-min intervals. No shorter lived activity has been observed in the initial stages and the whole sample decays with a half-life of 3.1 h. The decay curve of another sample of Cd^{117}, irradiated for 3 h and chemically purified, measured under identical conditions, was exactly the same as the above decay curve.

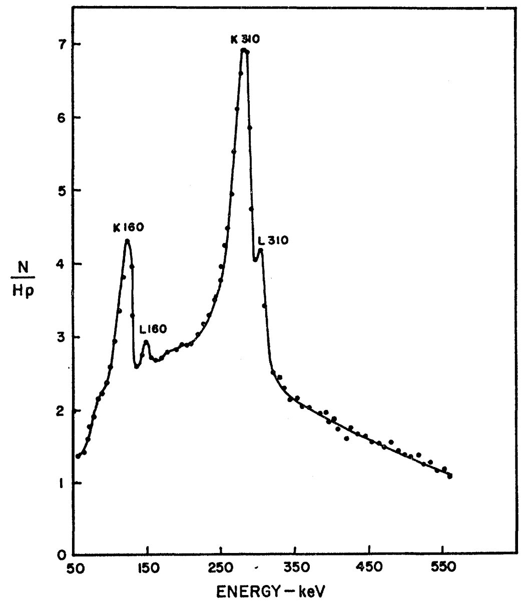

FIG. 1. Internal conversion electron spectrum of $Cd^{117} \rightarrow In^{117} \rightarrow Sn^{117}$ in Siegbahn-Slätis beta-ray spectrometer.

The conversion electron spectrum of Cd^{117} was studied in an intermediate image beta-ray spectrometer, two hours after the end of irradiation, with In^{117} present in equilibrium with Cd^{117}. Two conversion lines corresponding to gamma energies 160 and 310 keV are observed (Fig. 1). The 160 keV is a strong transition in the decay of $In^{117} \rightarrow Sn^{117}$ and the 310 keV is an isomeric transition in In^{117}. The conversion electron spectrum shows that there is a considerable build up of the 310-keV isomeric level in In^{117} due to the feeding of this level by beta and gamma transitions. The conversion line corresponding to the previously reported[4] isomeric transition of energy $\sim$440 keV and 20% intensity is not observed.

The above observations do not indicate the presence of a Cd^{117} isomer with a half-life shorter than three hours. The possibility of two isomers of nearly equal half-life

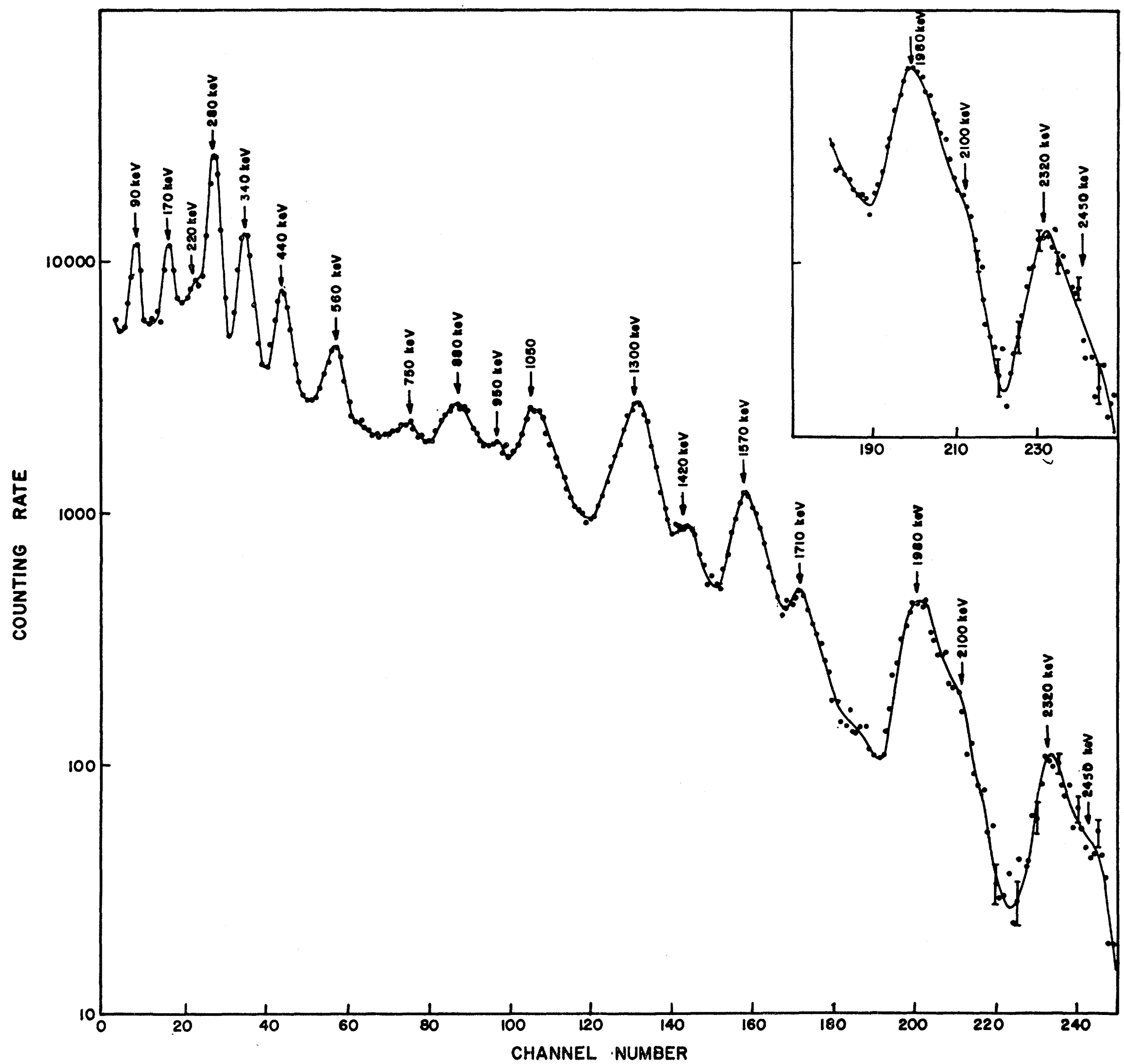

FIG. 2. Cd^{117} gamma-ray spectrum. In the inset is shown the high-energy part of the gamma spectrum with 2 in. of lead absorber.

has been pointed out recently[7] and this seems to be more consistent with the above results. But again no conversion line corresponding to an isomeric transition above 80 keV has been observed in the spectrum of Fig. 1 other than 160 and 310 keV. Spectrum of conversion electrons of energy less than 80 keV was not studied and the possibility of a highly converted isomeric transition in this energy region cannot be ruled out. However, the expected spins and parities for the isomers are $1/2^+$ and $11/2^-$ and the $E5$ isomeric transition of energy $\lesssim 100$ keV would be highly improbable. The isomeric transition at such low energies could be possible through a $d_{3/2}$ state if it is present in between $h_{11/2}$ and $s_{1/2}$ states.

[7] C. D. Coryell (private communication); C. W. Tang and G. E. Gordon, MIT Laboratory for Nuclear Science, Progress Report No. NYO-10063, p. 38, 1963 (unpublished).

IV. MEASUREMENTS FOR THE STUDY OF THE ENERGY LEVELS OF In^{117}

A. Gamma-Ray Spectrum

The singles gamma-ray spectrum as taken with the source at a distance of 15 cm from a 3-in.×3-in. NaI(Tl) crystal is shown in Fig. 2. Here the source used was the one irradiated for a period of five hours and the spectrum was recorded on a 512-channel analyzer within five minutes after the chemical purification. The various gamma rays extend from 90 to 2450 keV in energy. Direct transitions of energies of 2450 and 2100

TABLE I. Intensities of the gamma rays from singles and coincidence spectra. The brackets show the composite peak in singles spectrum where the nearby gamma rays are not resolved.

E_γ, keV	Relative intensity: Singles spectrum	Relative intensity: Coincidence spectra	E_γ, keV	Relative intensity: Singles spectrum	Relative intensity: Coincidence spectra
90±10	18±6		950±20	19	
160±15 }	25±10	6	1050±15 }	46±5	22
180±15 }		24	1070±15 }		24
220±10	9	9	1130±20	14±3	
280±5	100		1240±15	27±4	25
310 }			1300±10	82±8	8
320±10 }	66	35	1380±15 }	26±5	18
340±15 }			1410±15 }		
430±10 }	55±10	5	1570±20 }	53±5	25
440±10 }			1580±10 }		
570±15	33	18	1700±20	14±4	
630±10	5		1980±15	30±4	
720±15	5		2100±20	6±2	
750±15	13±3	10	2310±15	8±2	
840±10	18±4		2440±20	3±1	
880±10	25±5	24			

keV are indicated from the broadening of the more intense 2320- and 1980-keV photopeaks. This is confirmed by studying the singles spectrum with a 2-in.-thick lead absorber in between the source and crystal and thus reducing the summing probability of low-energy cascade gamma rays to a large extent. Such a spectrum as shown in the inset of Fig. 2 clearly shows the presence of the 2450- and 2100-keV transitions and that they are not due to the summing of low-energy gamma rays. The gamma rays of energy 160, 310, 560, 710, 830, and 1020 keV are present in the decay of $In^{117} \rightarrow Sn^{117}$. Gamma rays in the same energy region are also observed in $Cd^{117} \rightarrow In^{117}$ decay. This has been confirmed from the gamma-gamma coincidence study. The gamma spectrum has been analyzed in the usual way using standard line shapes. Any small contribution of Cd^{115} has been corrected for by taking the singles spectrum of the same source the next day. The intensities of various gamma rays corrected for photopeak efficiency and normalized to a value of 100 for the intensity of the 280-keV gamma ray are given in Table I. In this table the intensities of the gamma rays which are also present in $In^{117} \rightarrow Sn^{117}$ are inaccurate to the extent of the growth of In^{117} in a period of 5 min elapsed between the chemical separation and actual recording of the spectrum. The intensities of 90 and 160 keV are uncertain due to the large number of Compton subtractions.

TABLE II. Gamma-gamma coincidence data.

Gamma ray in gate, keV	Gamma rays in coincidence, keV
1700	280, 440, 750
1570	90, 160, 280, 350, 430
1410	180, 280, 330, 440, 570, 880, 1070
1300	90, 170, 230, 280, 340, 440, 750, 880, 1070
1070	90, 180, 280, 320, 440, 880, 1050, 1250, 1380
880	90, 170, 280, 340, 440, 830, 1050, 1250, 1380
570	340, 1410

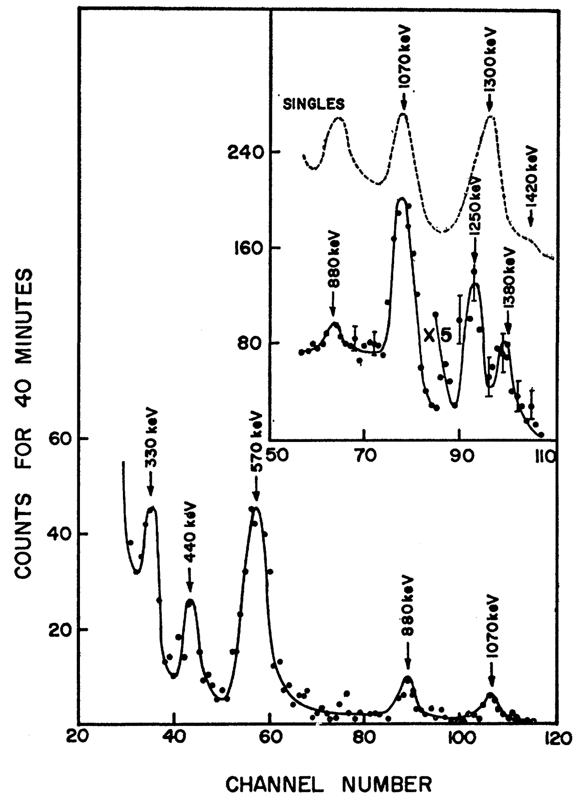

FIG. 3. Coincidence gamma-ray spectrum with 1410-keV photopeak region in the gate. In the inset is shown the gamma spectrum in coincidence with 1070-keV photopeak.

B. Gamma-Gamma Coincidences

The gamma-gamma coincidence measurements have been carried out with two 3-in.×3-in. NaI(Tl) crystals arranged at 90° or 180° with proper anti-Compton shields in either geometry to prevent spurious coincidences. A standard fast-slow coincidence circuit with a resolving time $2\tau = 0.12$ μsec has been used. The coincidence spectra were recorded on a 512-channel analyzer. Coincidence spectra with photopeaks of various gamma rays in gate have been studied and results are given in Table II.

The 2320-keV gamma ray has not been observed in coincidence with any other gamma ray. The 1980 keV showed a weak coincidence with 340 keV. The 1700-keV gamma ray has been observed in coincidence with 750-, 440-, and 280-keV gamma rays. As the 1700 keV is a weak transition, the two detectors in this case were placed at 180°.

The coincidence with 1570 keV has been studied with the two detectors at right angles. Photopeaks corresponding to 90-, 160-, 280-, 350-, 430-, and 570-keV energies were observed in this coincidence. The 570-keV peak observed in the coincidence spectrum was due to the partial acceptance of the 1410-keV gamma ray in the gate.

The gamma spectrum in coincidence with 1410-keV region is given in Fig. 3. The 1380 keV and a part of 1300 keV are also included in this gate. The observed peaks at 1070, 880, and 440 keV are attributed to the coincidences with 1380-keV gamma ray. Only 570-keV gamma ray is in coincidence with 1410 keV. This is confirmed by studying the coincidences with the 1070-, 880-, and 570-keV gamma rays described below. The 340-keV gamma ray could be in coincidence with either 1380 or 1410 keV or both. The very-low-intensity coincident photopeaks at 1070 and 880 keV shown in the spectrum in Fig. 3 taken at right-angles geometry, have been confirmed by repeating the same observation at 180° geometry in which case much stronger coincidences have been observed.

The coincidence gamma spectrum with 1300-keV photopeak in gate is shown in Fig. 4. This spectrum exhibits all the gamma rays in coincidence with the 1300 as well as the 1250-keV gamma rays which is also included in the gate. The 90-, 180-, 230-, 330-, 440-, 880-, and 1070-keV photopeaks are all attributed to coincidence with 1250-keV gamma ray. The last two have been confirmed from the study of the coincidences with the 880- and 1070-keV gamma rays. The peak at 560 keV is wholly due to the partial acceptance of the 1410-keV gamma ray in the gate. The 230-keV peak could not be due to any back scattering as the two detectors were at 90° in this case. The 280-keV gamma ray is in strong coincidence with 1300 keV. This is confirmed from the study of the spectrum in coincidence with the 280-keV photopeak in gate as given in the inset of Fig. 4. In this case the photopeak in coincidence is at 1300 keV. The weak coincidences of 280 keV with 1380- and 1570-keV gamma rays appear to be masked by the strong coincidence with 1300 keV. A photopeak has also been observed at 1700 keV.

The gamma spectrum in coincidence with 1070-keV photopeak is shown in the inset of Fig. 3. It is clear from this spectrum that the 1070-keV gamma ray is in coincidence with 1380, 1250, and 880 keV and also with a gamma ray of energy in the neighborhood of 1070 keV. The strong coincidence with a gamma ray of energy around 1070 keV is attributed to a 1050–1070-

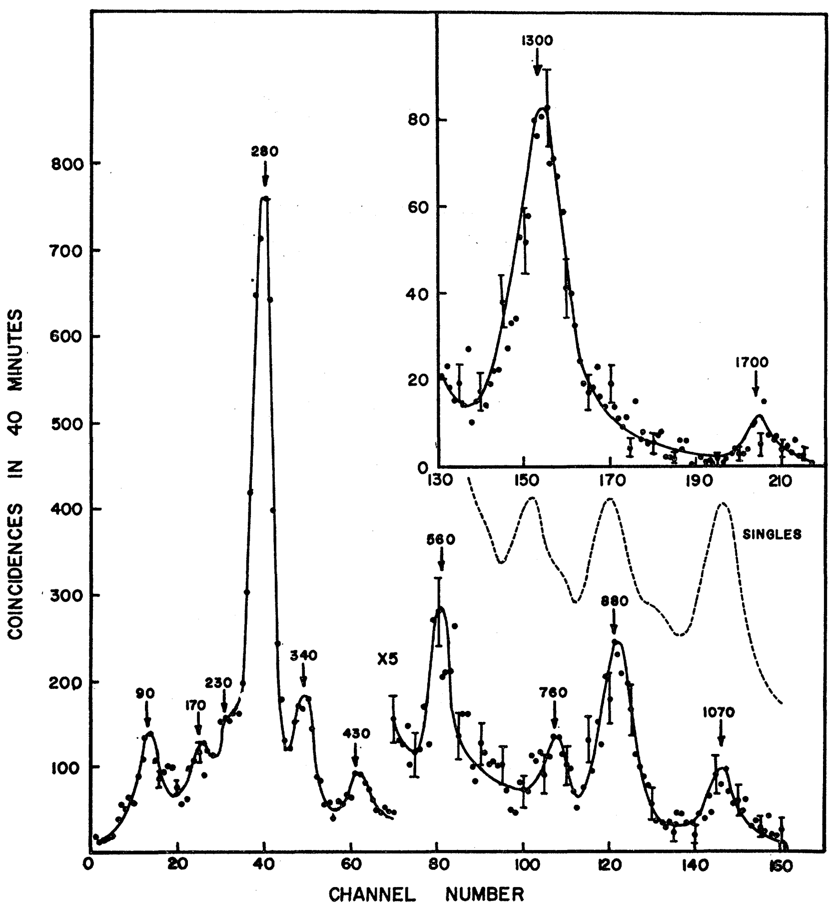

FIG. 4. Coincidence gamma-ray spectrum with 1300-keV photopeak in the gate. In the inset is shown the gamma-ray spectrum in coincidence with 280-keV photopeak.

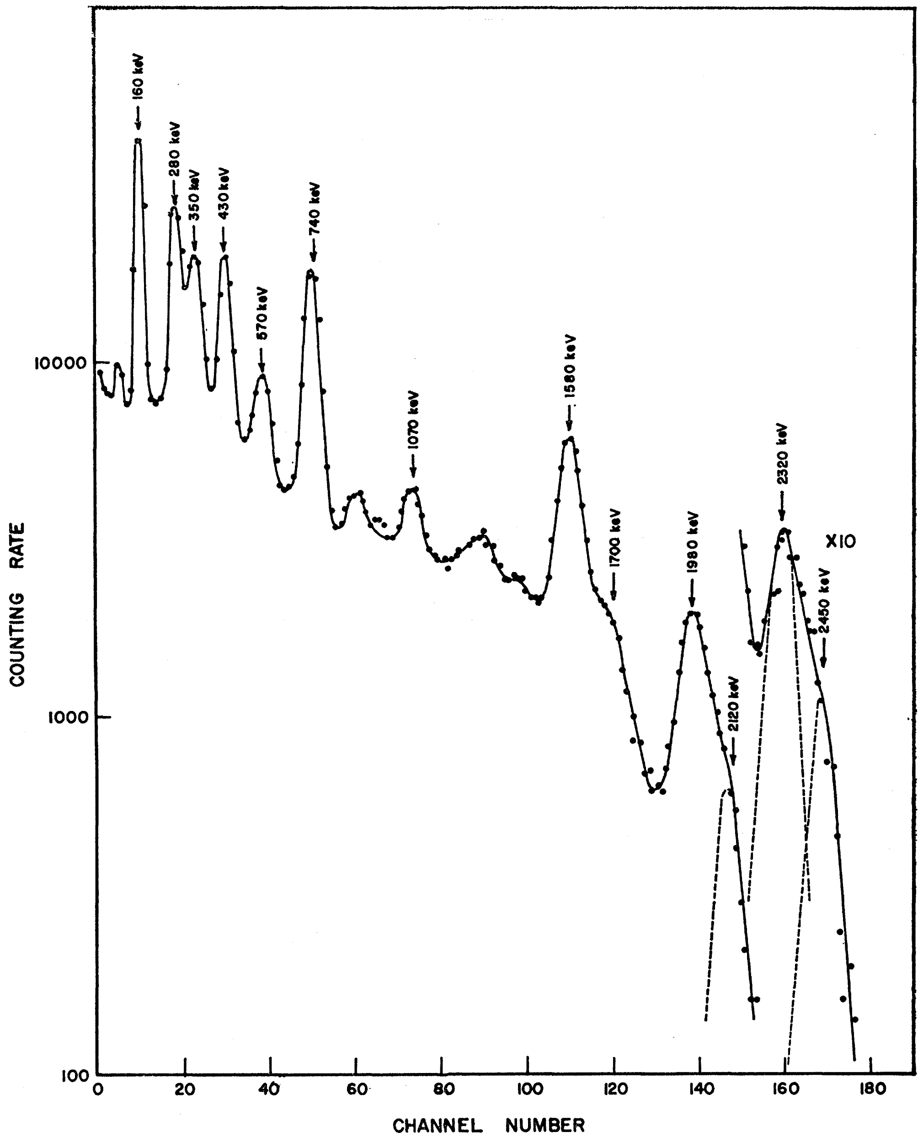

FIG. 5. The total absorption gamma-ray spectrum of Cd^{117}.

keV cascade. From the analysis of the low-energy side of the coincidence spectrum (not included in the figure) weak coincidences of 1050-keV gamma ray with 90, 180, 280, 320, and 440 keV have been observed.

In the study of the coincidences with 880-keV gamma ray, clear photopeaks were observed in the region of 1050 and 1250 keV and also an indication of a photopeak at 1380 keV. This confirmed the coincidences of 1050-, 1250-, and 1380-keV gamma rays with 880 keV as mentioned above. In addition to these, the 880-keV gamma ray showed coincidences with a gamma ray of energy around 880 keV itself and with 90, 170, 280, 340, and 440 keV.

The coincidence spectrum with 570-keV photopeak in gate showed strong coincidences with 1410-keV gamma ray and very weak coincidences with 340-keV gamma ray.

The relative intensity of some of the gamma rays calculated from the analysis of the coincidence spectra are also included in Table I. These intensities are not expected to be very accurate due to the complex nature of the cascades and also due to the subtraction of the Compton contribution of many gamma rays from the gate counts as well as in the analysis of the coincidence spectra. However, they give a fairly good idea of the intensity in those cases where gamma rays of nearby energies occur at two places just as in the case of 1380, 1410 keV, 180, 160 keV, 880, 830 keV, etc. The intensity of 90- and 160-keV transitions from the singles spectrum is rather low due to the uncertainty involved in the large number of Compton subtractions and also due to

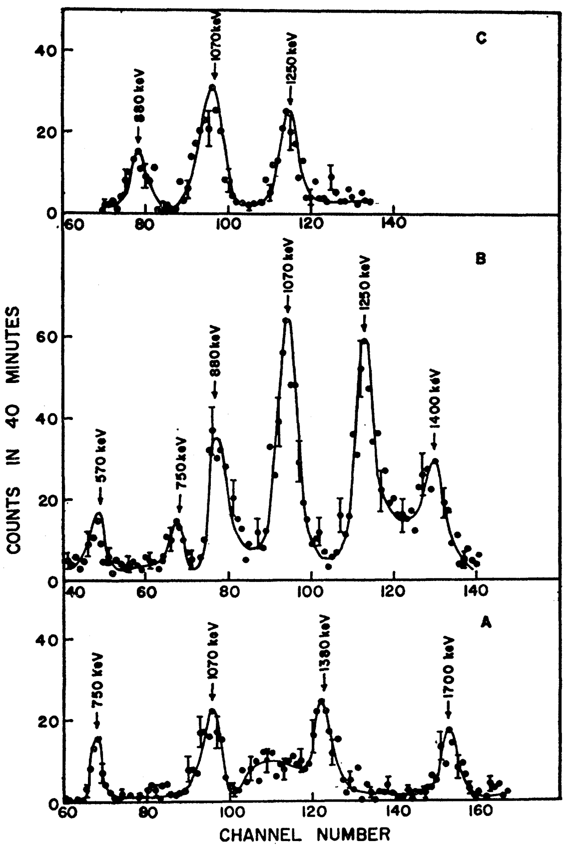

FIG. 6. Sum-coincidence spectra with (a) 2450-keV sum peak in gate, (b) 2320-keV sum peak in gate, and (c) 2120-keV sum peak in gate.

their large internal conversion. The larger intensities of the gamma rays in the 570- and 320-keV region in singles spectrum are due to the contribution of the 560- and 310-keV gamma rays from In^{117} and In^{117m}.

C. Total Absorption Gamma-Ray Spectrum

The gamma-ray spectrum of Cd^{117} has been studied in almost 4π geometry by introducing the source in the well of a 3-in.×3-in. NaI(Tl) crystal. In such a spectrum cascade gamma rays sum up to a large extent giving rise to distinct sum peaks which help in identifying the energy levels. The broadening of the highest energy peak in this spectrum shown in Fig. 5 is an indication of two peaks corresponding to 2320 and 2450 keV. They have been analyzed by fitting the line shapes of energy 2300 and 2500 keV obtained from the spectrum of Na^{22} and Co^{60} taken with the source inside the well. This indicates the existence of energy levels at 2450 and 2320 keV. In a similar way the broadpeak at 1980 keV is an indication of two levels at 1980 and 2120 keV. As is clear from the spectrum in Fig. 5 the energy levels at 2450 and 2120 keV are much less populated than those at 2320 and 1980 keV. The strong peak at 1580 keV is due to a strong 280–1300-keV cascade above the isomeric level at 310 keV, and indicates the energy level at 1890 keV. It may be stated here that such sum peaks occur at slightly higher energy due to the nonlinear response of NaI(Tl) crystal[8] and this effect has been taken into account while identifying the peaks at 2450, 2320, 2120, and 1980 keV.

D. Sum-Coincidence Measurements

In order to further study the cascade gamma rays obtained from the decay of 2450-, 2320-, and 2120-keV excited states the sum-coincidence technique[9,10] has been utilized. The coincidence spectra corresponding to 2450-, 2320-, and 2120-keV sum peaks are shown in Fig. 6. The decay mode of 2450-keV excited state is clear from Fig. 6(A) where four photopeaks corresponding to energy 750, 1070, 1380, and 1700 keV have been observed. This further confirms the 1700–750-keV and 1070–1380-keV cascades. Similarly, the coincident photopeaks with 2320-keV sum peak [Fig. 6(B)] confirm the 1250–1070-keV and 1400–570–340-keV cascades. The 880-keV peak is due to 1250–180–880-keV cascade. The photopeak at 750 keV is due to the acceptance of a small part of the 2450-keV sum peak in the narrow region of the 2320-keV peak taken in the gate. The gamma cascades arising from the decay of the 2120-keV excited state are shown in Fig. 6(C). Here the broad photopeak at 1070 keV indicates the 1070–1050-keV cascade. Another cascade of 1250–880 keV is also present in this coincidence. The width of the gate was kept as one volt at 2120 keV in order to minimize any contribution of 2320 and 2450 keV.

E. The Beta Spectrum

The beta spectrum of Cd^{117} has been studied with the Siegbahn-Slätis beta-ray spectrometer. The beta source

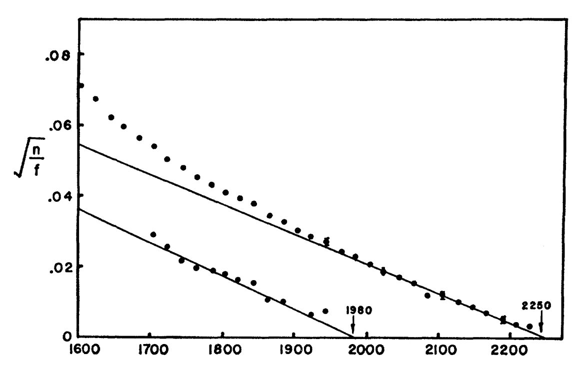

FIG. 7. Fermi plot of the beta spectrum of Cd^{117} in Siegbahn-Slätis spectrometer.

[8] H. G. Devare and P. N. Tandon, Nucl. Instr. **22**, 253 (1963).
[9] A. M. Hoogenboom, Nucl. Instr. **3**, 57 (1958).
[10] S. Jha, H. G. Devare, M. Narayana Rao, and G. C. Pramila, Proc. Indian Acad. Sci. Sect. A, **50**, 303 (1959).

TABLE III. Beta transitions in the decay of Cd^{117} and Cd^{117m}. The log *ft* values of the beta transitions in the decay of Cd^{117m} have been calculated on the assumption that this isomer mainly decays to the top four levels and the level at 1700 keV.

E_β, keV	Level fed	Relative intensity, %	log *ft*
A. Cd^{117m}			
250	2450	12	4.4
400	2320	30	4.8
580	2120	17	5.5
720	1980	29	5.6
1000	1700	12	6.3
B. Cd^{117}			
670	1890	79	5.0
1810	750	4	8.0
1970	590	7	7.8
2250	310	10	7.8

was made from a sample irradiated for 8 h in a flux of 10^{12} neutrons/cm²/sec and chemically purified. Because of the presence of In^{117}, with beta end point of 1770 keV, grown from the Cd^{117} parent during the period of observation, only the high-energy portion of the beta spectrum was studied. The Fermi analysis of the beta spectrum above 1600 keV (Fig. 7) corrected for decay of the source, showed the highest energy group with end point 2250 keV and the next highest energy group with end point 1970 keV. The relative intensities of these two beta groups were calculated from the analysis of this Fermi plot. The intensities of all other beta groups were calculated from the gamma-ray intensities. The intensities and the log *ft* values are given in Table III.

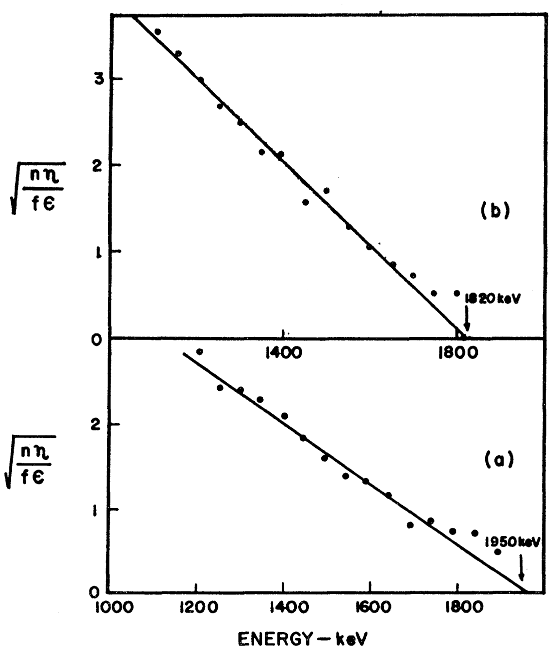

FIG. 8. Fermi plot of the beta spectra in coincidence with (a) 280-keV gamma ray and (b) 440-keV gamma ray.

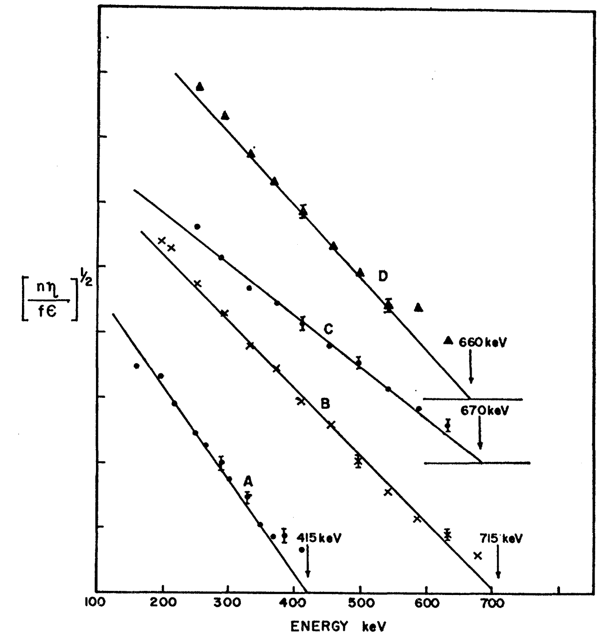

FIG. 9. Fermi plot of the beta spectra in coincidence with (a) 2320-keV gamma ray, (b) 1980-keV gamma ray, (c) 1570-keV gamma ray, and (d) 1300-keV gamma ray.

F. Beta-Gamma Coincidence

The end points of beta spectra feeding different excited states of In^{117} have been determined by beta-gamma coincidence method. In this study, the same coincidence set up as described earlier was used with an anthracene beta detector in place of one of the NaI(Tl) crystals. The Fermi plots of the beta spectra in coincidence with 280- and 440-keV gamma rays showed end points at 1950 and 1820 keV, respectively (Fig. 8). The beta spectra in coincidence with 1300-, 1570-, 1980-, 2320-, and 2450-keV gamma rays were also repeated, using a 4π plastic scintillation spectrometer for recording the beta spectra. The Cd^{117} source was chemically purified, deposited on a Mylar film of 400 μgm/cm² thickness and was then placed in proper position. The gamma rays were detected in a 3-in.×3-in. NaI(Tl) crystal. The Fermi analysis of the beta spectra in coincidence with 1300-, 1570-, 1980-, and 2320-keV gamma rays is shown in Fig. 9. It is important to note that the same beta end point at energy ~660 keV is obtained in coincidence with 1050-, 1300-, and 1570-keV gamma rays. The 2450-keV gamma ray has been observed in coincidence with a beta group of end-point energy ~250 keV.

V. DISCUSSION

The proposed decay scheme of Cd^{117} is given in Fig. 10. As a direct transition of energy 2450 keV has been observed the highest energy level is shown at the same energy. The 750–1700-keV and 1380–1070-keV cascades

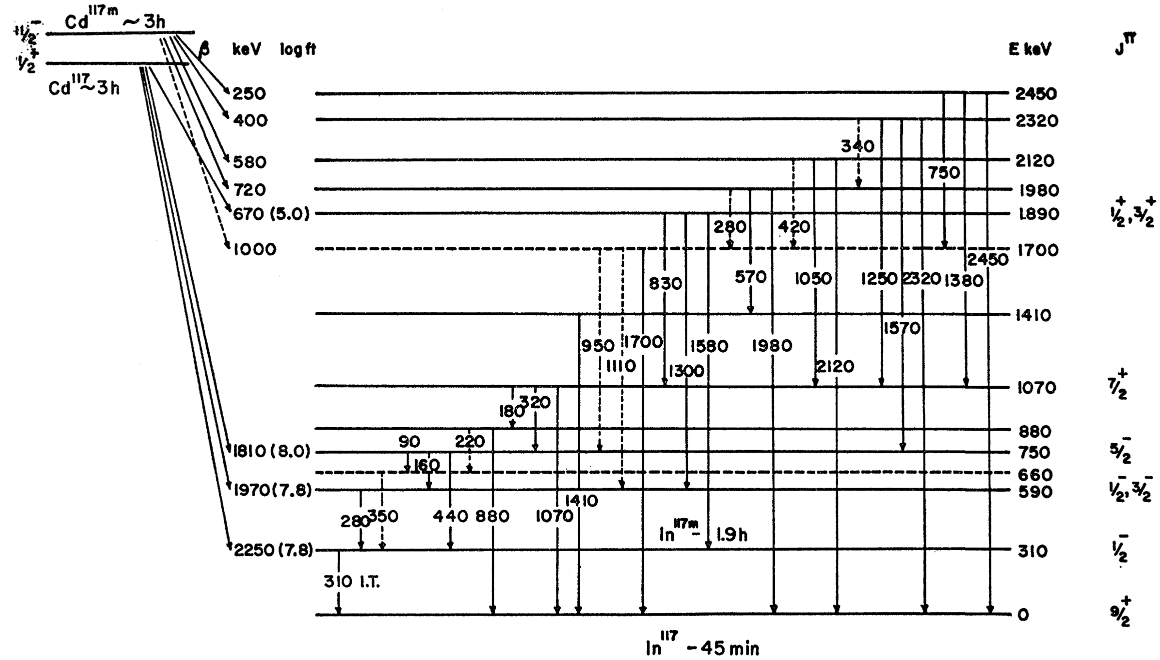

FIG. 10. Decay scheme of Cd^{117}.

as obtained from gamma-gamma and sum-coincidence measurements further support the highest energy level to be at 2450 keV. Similarly direct transitions of the proposed 2320-, 2120-, and 1980-keV excited levels to the ground state of In^{117} have been observed. The 2120-keV excited level mainly decays through the 1050–1070-keV cascade and the crossover transition is comparatively weak. The direct transition from the 2320-keV level to the ground state is also rather weak in intensity. On the other hand, the ground-state transition from the 1980-keV excited level is fairly strong. No transitions to the 2320- and 2120-keV levels from the 2450-keV level have been observed. The 1980-keV level is partially fed from the 2320-keV level by a weak gamma ray of energy 340 keV. The level at 1890 keV mainly decays by the 1300–280-keV strong cascade to the isomeric state of In^{117}. Direct transition of the 1890-keV level to the ground state has not been observed, but there is a 1580-keV crossover transition to the isomeric state at 310 keV. The beta spectra in coincidence with 1300- and 1580-keV gamma rays show the same end point at $\sim$670 keV and these gamma rays are therefore shown to arise from 1890-keV level. The level at 1410 keV is proposed on the basis of 1410-570-keV cascade. The 570-keV gamma ray is shown to arise from the 1980-keV excited level. The 1050–1070-keV and 1250–1070-keV cascades as established by coincidence measurements indicate the presence of a level at 1070 keV. The beta-gamma coincidence studies do not indicate any beta feeding to this level. It is populated mainly by the 830-, 1050, 1250-, and 1380-keV gamma transitions. Since 1250-keV gamma ray shows strong coincidence with 880- and 180-keV gamma rays with almost equal intensity, a level at 880 keV is proposed. The 1070 keV is the crossover transition of 880 and 180 keV. The level at 880 keV is also supported from the coincidences with 880-keV gamma ray where 180 keV is almost equal in intensity to the sum of the intensities of the 830-, 1050-, 1250-, and 1380-keV gamma rays. The beta feeding to 880-keV level is negligible. The 750- and 590-keV levels are proposed on the basis of the end points of beta spectra in coincidence with 440- and 280-keV gamma rays, respectively. These 750- and 590-keV levels as well as the isomeric level at 310 keV are fed by strong gamma transitions. The beta branchings to these levels are weak.

The 1700-keV level has been proposed mainly on the basis of the 1700–750-keV cascade as observed in gamma-gamma and sum-coincidence measurements. Since a direct ground-state transition from the 750-keV level is not possible from spin and intensity considerations, the 1700-keV gamma ray could not be fitted between 2450- and 750-keV levels. The 950- and 1110-keV transitions have also been shown to arise from this 1700-keV level, but they have not been confirmed by gamma-gamma coincidence measurements. The 1580-keV gamma ray has shown clear coincidences with 90, 160, 280, 350, and 440 keV and this suggests that in addition to the 1580-keV crossover transition of 1300–280-keV cascade, a transition with almost equal energy should be arising from one of the excited states above 1890 keV. Such a 1570-keV transition is, therefore, shown between the 2320- and 750-keV states and the observed coincidences are explained by proposing a level at 660 keV. Then the results of sum coincidence and the coincidence of 1250-keV transition with 90, 320, and 440 keV are also explained.

It has already been mentioned that there is evidence for an isomer of Cd^{117} with a half-life almost equal to that of the ground state. The present beta-gamma coincidence results support the presence of such an isomer. The end points of the beta groups obtained in coincidence with 2450-, 2320-, and 1980-keV gamma rays when compared with those in coincidence with 1300- and 1570-keV gamma rays indicate that the beta feeding to the 2450-, 2320-, and 1980-keV levels is from an isomer $\sim$140 keV above the ground state of Cd^{117}. The same measurements indicate that the total decay energy should be 2700$\pm$40 keV. Thus from energy considerations the observed beta group of highest end-point energy 2250 keV is due to the decay of the ground state of Cd^{117} to the isomeric state of In^{117} at 310 keV. The log ft of this transition is 7.8 and it is first forbidden. This suggests that the ground-state configuration of Cd^{117} is $s_{1/2}$ or $d_{3/2}$ since the In^{117} isomer is known[11] to have $p_{1/2}$ configuration. According to shell model, the ground state and isomeric state of Cd^{117} should be $s_{1/2}$ and $h_{11/2}$, respectively. Taking the isomeric state as $11/2^-$, a beta feeding from this state to the known $9/2^+$ ground state[11] of In^{117} is expected. Such a beta transition of end-point energy 2700 keV has not been observed, even though a 2% intensity is expected if a logft $\sim$9 is assumed for such a transition. It is not understood why this beta transition is absent. At the same time any $E5$ isomeric transition from $11/2^-$ to $1/2^+$ is highly improbable on the basis of Weisskopf estimate, but if a $3/2^+$ state exists in between $11/2^-$ and $1/2^+$ states then a $M4$ transition could be possible. The half-life of such a transition in the energy range of interest (100 to 140 keV) is of the order of one or two days and would be much more if the energy is less than 100 keV. In Sn^{119}, where also the neutron number is 69, such $11/2^-$, $3/2^+$, and $1/2^+$ states have been observed.[12] Here the $3/2^+$ state is 24 keV above the $1/2^+$ ground state. In a similar way, the possible $3/2^+$ state in Cd^{117} may be lying about 20 keV above the $1/2^+$ ground state. The conversion line spectrum as given in Fig. 1 does not indicate the existence of any conversion line corresponding to a transition around 140 keV. The two conversion lines as seen in this spectrum are all due to the 160-keV strong transition in Sn^{117} and 310-keV isomeric transition in In^{117}. This has been confirmed from the measurement of the relative intensities of 160- and 310-keV photopeaks obtained from the study of the gamma spectrum of chemically separated In^{117}. Thus, a $M4$ isomeric transition between the $11/2^-$ and a $3/2^+$ states appears to be unlikely.

Thus, in the absence of any isomeric transition and any other strong beta transition from Cd^{117m} to the ground state or low excited states of In^{117}, it seems that the isomeric state of Cd^{117} is mainly decaying by beta emission to the four top levels of In^{117}. On this basis the log ft values of the beta transitions to 2450-, 2320-, 2100-, and 1980-keV levels are seen to be around 5. Based on these log ft values the above beta transitions appear to be allowed in character and indicate the possibility of negative parity to these four levels. Their possible spins may be 9/2 or 11/2 as 13/2 is unlikely because of the observed transitions to ground from these states.

The levels at 1890, 750, and 590 keV are fed from the ground state of Cd^{117}. The log ft values of the beta transitions to these states are 5.0, 8.0, and 7.8, respectively. On the basis of log ft value the spin and parity of 1890-keV level may be $1/2^+$ or $3/2^+$. As the 750-keV level is also fed from the 2320-keV level it may have its spin and parity $5/2^-$. This is consistent with the log ft value of 8.0 to this level. The 590-keV level is strongly fed from the 1890-keV level and the beta transition to this level is first forbidden. Both these facts suggest that it may have its spin and parity as $1/2^-$ or $3/2^-$.

The low-excited levels of In^{117} appear to be similar to those[13,14] of In^{115}. The high-energy levels, which appear to have negative parity, may be due to the breaking up of a proton or neutron pair as the energy $\sim$2000 keV of these levels is sufficiently high.

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