Level structure of odd-mass In nuclei and the unified model. II. ^{117}In levels populated in the decay of ^{117}Cd isomers

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(Received 27 October 1978)

Ge(Li) detectors have been used to perform singles, coincidence, and angular correlation measurements on γ rays present in the decays of 2.5-h ^{117}Cd^{g}(1/2$^+$) and 3.4-h ^{117}Cd^{m}(11/2$^-$). A total of 112 of the 114 γ rays observed in the decay of ^{117}Cd^{g} and all 71 of the γ rays observed in the decay of ^{117}Cd^{m} have been placed in a level scheme consisting of 46 excited states. A total of 51 different γ-γ cascades were measured at 90° and 180°. The β branchings from ^{117}Cd^{g} to ^{117}In^{m} and ^{117}Cd^{m} to ^{117}In^{g} were determined to be 20.4% and $<1\%$, respectively. The thermal neutron cross sections for the production of ^{117}Cd^{g} and ^{117}Cd^{m} were determined to be 43 ± 2 mb and 8 ± 1 mb, respectively. Spin and parity assignments for the levels of ^{117}In were made in many instances. The level structure is discussed in relation to the unified model calculation and possible one-proton–two-neutron configurations.

[RADIOACTIVITY ^{117}Cd^{g} and ^{117}Cd^{m} [from ^{116}Cd(n,γ)]; measured E_γ, I_γ, γ-γ coin, γ-$\gamma(\theta)$; deduced β branch, logft. $\sigma(n,\gamma)$, A_{22}, δ. ^{117}In deduced levels, J, π. Enriched target, Ge(Li) detectors, Compton suppression.]

I. INTRODUCTION

In a recent paper (I), Heyde, Waroquier, and Meyer[1] presented the results of a new comprehensive unified model calculation to interpret the structure of states in the odd-mass In isotopes. They noted the presence of a number of observed properties that are not accounted for in weak coupling hole-phonon models[2,3] as well as the difficulties encountered by more recent Nilsson model treatments.[4,5] For their unified model calculations, they considered both single-hole and one-particle–two-hole (1p-2h) configurations (seniority $v=1$ and $v=3$), together with the quadrupole and octupole vibrations of the underlying core (Sn) nucleus. Using this single basis, the 1p-2h states, hereafter referred to as particle-hole states, could readily mix with the hole-core states in a natural way. They compared their results with the observed properties of ^{113}In and ^{115}In and showed that the unified model could account for many of the important features of the low-lying, positive-parity, particle-hole states, including level energies, γ-ray branchings, transfer reaction strength, and Coulomb excitation $B(E2)$ values.

The values of Q_β for the decays to ^{113}In and ^{115}In do not permit study of those levels above 1400 keV. However, the higher value of Q_β for the decay of the ^{117}Cd isomers (~2500 keV) provides an excellent opportunity to extend the comparison of the unified model to higher energy in another In isotope. Because the recent studies[6,7] of ^{117}Cd^{m,g} decay were not in agreement for the assignments of a number of γ rays and levels, and since spin and parity assignments have not been made for many of the agreed levels, we have undertaken this study to determine an accurate scheme for the levels of ^{117}In populated in ^{117}Cd decay which can serve as a test of the unified model description for ^{117}In levels.

II. EXPERIMENTAL PROCEDURES

A. Singles spectra

The sources of ^{117}Cd isomers were prepared by the thermal neutron irradiation of samples of varying sizes of CdO enriched to 96% in ^{116}Cd.

One factor of uncertainty in the previous studies of ^{117}Cd^{m,g} decay has been the assignment of weak γ rays. With half-lives of 2.5 h and 3.4 h, it is not possible to prepare relatively pure sources of either isomer. For low-intensity γ rays the problem is increased as it is difficult to track their half-lives with high accuracy at times long after irradiation. We solved this problem by utilizing the Compton-suppression spectrometer[8] (CSS) at the Lawrence Livermore Laboratory (LLL) to follow the decay of several samples for 36-h periods as well as to accumulate spectra for a number of fresh samples for shorter periods of time. The CSS is equipped with a moving source holder that can maintain a constant count rate over sample strength variations of ~20. It was possible to start with very active samples far from the detector and maintain a relatively constant count rate for a long period of time. Isomer identification was then accomplished by normalizing the peak areas for γ rays known to belong to a single isomer.

Precise relative intensities were determined from spectra accumulated on well-calibrated large-volume detectors. Energy values were determined by counting ^{117}Cd, simultaneously, with a number of nuclides having well-known γ-ray energies. The spectra were analyzed by the GAMANAL program[9] at LLL.

B. Coincidence spectra

The γ-γ coincidence and angular correlation studies were carried out using the University of Maryland Nova-computer-based buffer tape system at the National Bureau of Standards Reactor. The coincidence studies utilized a pair of 55 cm^3 true-coaxial Ge(Li) detectors in a 180° configuration with a separation of 1 cm. Lead sheets 1.6 mm thick with a hole about 1 cm diam were used to surround the samples and reduce Compton scattering between the two detectors. A coincidence time window of 60 nsec was used and 1.2×10^7 events were recorded.

Analysis was conducted at the University of Maryland computer center using a program which permits the subtraction of Compton produced events utilizing structureless areas on both sides of the gated peak. We tabulate the γ-ray energy and intensity values, placement, and observed coincidences for the decay of each isomer in Tables I and II.

Only γ rays showing a 2.5-h or 3.4-h half-life are listed in Tables I and II. One or more components of some of the multiplets noted in Tables I and II arose from contaminant activities such as ^{115}Cd isomers and ^{117}In isomers. The samples also showed small amounts of ^{110}Ag^m and ^{182}Ta when counted long after the ^{117}Cd isomers had decayed, but the activity levels were too low to be observed during the first 36 h after the end of the irradiations.

C. Angular correlation measurements

The angular correlation studies were designed to take advantage of the fact that $A_{44} \equiv 0$ for cascades involving pure dipole transitions and for cascades in which the intermediate state has a $\frac{3}{2}$ spin.[10] In the decay of ^{117}Cd^g $(\frac{1}{2}^+)$, allowed β decay populated many $\frac{1}{2}^+$ and $\frac{3}{2}^+$ states which branch to the $\frac{3}{2}^-$ level at 588 keV via $E1$ transitions. Measurements were made at 90° and 180° because only two points are required to determine the A_{22} value. The detectors were fixed at a distance of 15 cm from the sources and 3×10^6 events were accumulated at each angle. Small, but non-negligible corrections were made for the finite size of the detectors.[11] For each cascade and angle, two independent data points were obtained, one by gating detector A to determine coincidences in detector B and the other by gating detector B to determine coincidences in detector A. The final results is the average of these two values.

In Table III we have tabulated the γ-ray cascades studied according to their intermediate level energies. We show in brackets [ ] those spin sequences and their theoretical A_{22} values which are excluded by the observed data. No data are listed for the 344-keV (659-keV level) transition as the 60-nsec half-life permits too much deorientation for the data to be useful. For the 434-keV transition from the 5-nsec 749-keV level $(\frac{1}{2}^+)$, the data are tabulated and observed to be consistent with the isotropy associated with spin-$\frac{1}{2}$ intermediate states. In addition, we have listed the δ values, where they can be determined, and have followed the sign convention of Taylor *et al.*[12]

D. Determination of absolute γ-ray intensities

The absolute intensities for the ^{117}Cd γ rays were determined by following the growth and decay of the 44-min ^{117}In$^g(\frac{9}{2}^+)$ and 117-min ^{117}In$^m(\frac{1}{2}^-)$ daughters. A ^{116}CdO sample was irradiated for 10 min and counted for 24 hours. These results were combined with our γ-ray intensity balance, the absolute ^{117}In γ-ray intensities,[13] and the assumption of negligible $E5$ internal transition (I.T.) intensity in the decay of ^{117}Cd^m to determine a 20.4% direct β branch from ^{117}Cd^g to ^{117}In^m $(\frac{1}{2}^+$ to $\frac{1}{2}^-)$ and a <1% direct β branch from ^{117}Cd^m to ^{117}In^g $(\frac{11}{2}^-$ to $\frac{9}{2}^+)$. The conversion from relative intensities for ^{117}Cd^g decay to absolute intensities is accomplished by multiplying the relative intensity values in Table I by 0.0187, and for ^{117}Cd^m, the values in Table II by 0.023.

E. Cross-section measurements

We measured the (n_{th}, γ) cross sections for the production of the ^{117}Cd isomers by comparison to the standard value of 37.2 ± 0.2 b for the ^{59}Co$(n_{th}, \gamma)^{60}$Co reaction.[14] A sample containing 4.83 mg of 96% enriched ^{116}CdO and 4.92 mg of ^{59}Co wire was irradiated in position RT-4 at the National Bureau of Standards Reactor, where the flux is 10^{13} n cm^{-2} sec^{-1} and the Cd ratio is greater than 100. We obtain cross sections of 43 ± 2 mb for the ^{116}Cd $(n_{th}, \gamma)^{117}$Cd^g reaction and 8 ± 1 mb

TABLE I. γ rays observed in the decay of 2.5-h $^{117}Cd^{g}$.

Energy[a] (keV)	Relative intensity[a,b]	Placement[c] (keV)	Coincident γ rays observed[d] (keV)
71.12 (2)	21 (3)	659- 588	
89.73 (1)	178 (10)	749- 659	71, 344, 497, 862, 963, 1035, 1142 1247, 1272, 1314, 1422, 1562
105.4 (1)	1.2 (6)	1997-1891	
131.4 (2)	0.6 (3)	880- 749	
132.7 (1)	1.2 (6)	880- 748	
160.8 (4)	14 (5)	749- 588	
171.05 (7)	1.4 (6)	1051- 880	
172.2 (1)	0.5 (3)	2064-1891	
179.4 (1)	5.3 (1.5)	1891-1712	220, 831, 880, 963, 1052
220.95 (4)	64 (4)	880- 659	71, 171, 179, 273, 284, 344, 387, 728, 831, 1116, 1183, 1229, 1290, 1430
221.0 (4)	3 (3)	2311-1891	1303
273.36 (2)	1520 (20)	588- 315	71, 89, 105, 160, 279, 292, 419, 439, 463, 831, 840, 850, 945, 965, 1116, 1229, 1259, 1290, 1303, 1408, 1430, 1433, 1475, 1521, 1583, 1723, 1739, 1756, 1867
279.8[e] (1)	6 (2)	2171-1891	
279.8[e] (1)	3 (2)	1891-1612	
284.9 (1)	4.5 (1.2)	1997-1712	
292.06 (4)	35 (4)	880- 588	273, 387, 728, 831, 1116, 1183, 1229, 1290, 1430
314.4 (4)	4 (2)	2311-1997	
315.30 (2)	I. T.	315- 0	
344.46 (1)	975 (20)	659- 315	89, 220, 387, 716, 831, 949, 963, 1052, 1116, 1125, 1142, 1232, 1247, 1272, 1290, 1314, 1337, 1362, 1430, 1450, 1562, 1652
387.98 (5)	17 (3)	1997-1609	220, 273, 292, 344, 728, 748, 861, 880, 949
397.2 (1)	11 (2)	2109-1712	273, 831, 880, 963, 1052
416.9 (2)	1 (1)	1468-1051	
419.81 (5)	10 (2)	2311-1891	273, 1303, 1576
434.19 (2)	533 (20)	749- 315	497, 627, 699, 862, 963, 1035, 1142, 1247, 1272, 1314, 1422, 1562, 1578, 1596
439.4 (1)	6 (4)	1028- 588	273, 969, 1143
453.8 (3)	2 (1)	2345-1891	
463.04 (3)	41 (3)	1051- 588	273, 840, 945, 1120, 1259
497.8 (2)	6 (2)	2109-1612	
500.6 (2)	0.8 (8)	2109-1609	
526.6[e] (5)	2 (2)	1554-1028	
527.0[e] (5)	8 (2)	2311-1784	
597.6 (3)	0.8 (8)	not placed	
627.0 (2)	6.3 (1.6)	1376- 749	
644.5 (2)	1 (1)	2112-1468	
660.83 (8)	6.1 (1.7)	1712-1051	
688.0 (3)	0.6 (6)	2064-1376	
699.6 (1)	13 (2)	2311-1612	89, 273, 344, 434, 862, 952
712.71 (6)	31 (8)	1028- 315	526, 969, 994, 1036, 1143, 1317
716.4 (1)	11 (2)	1376- 659	344
728.6 (1)	13 (2)	1609- 880	220, 292, 387, 736, 880
736.12 (8)	3.4 (1.8)	2345-1609	
748.05 (4)	30 (10)	748- 0	132, 387, 861, 964, 1249, 1316, 1562, 1597
757.6 (2)	1.5 (1.0)	not placed	
831.78 (4)	123 (4)	1712- 880	131, 179, 220, 273, 284, 292, 344, 397, 748, 880

TABLE I. *(Continued)*

Energy [a] (keV)	Relative intensity [a,b]	Placement [c] (keV)	Coincident γ rays observed [d] (keV)
840.18 (5)	44 (3)	1891-1051	171, 273, 463, 1051
850.72 (8)	6.5 (2.0)	1439- 588	
861.3 (4)	16 (10)	1609- 748	387, 748
862.59 (5)	33 (3)	1612- 749	89, 273, 279, 344, 434, 497, 699
880.71 (2)	216 (10)	880- 0	171, 179, 284, 387, 728, 736, 831, 1011, 1116, 1183, 1229, 1290, 1430
945.67 (3)	84 (4)	1997-1051	273, 463, 1051
949.6 (1)	12 (2)	1609- 659	273, 344, 387, 453, 736
952.3 (1)	7.5 (1.8)	1612- 659	
963.0 (1)	34 (3)	1712- 749	89, 179, 344, 434
964.6 (4)	3 (2)	1712- 748	
965.8 (2)	5 (2)	1554- 588	
969.30 (5)	24 (3)	1997-1028	273, 439, 712
970.4 (3)	3 (3)	2022-1051	1051
994.3 (4)	1 (1)	2022-1028	
1011.3 (3)	4 (2)	1891- 880	
1012.3 (3)	4 (2)	2064-1051	
1035.6 [e] (1)	13 (2)	1784- 749	
1036.0 [e] (4)	1 (1)	2064-1028	
1051.7 (1)	206 (10)	1051- 0	660, 840, 945, 970, 1012, 1120, 1259, 1276
1052.7 (1)	39 (8)	1712- 659	344
1061.1 (2)	3 (2)	2112-1051	
1116.56 (7)	57 (3)	1997- 880	220, 273, 292, 344, 880
1120.07 (9)	13 (2)	2171-1051	
1125.15 (8)	24 (2)	1784- 659	273, 344, 527
1142.42 (3)	91 (5)	1891- 749	89, 273, 344, 434
1143.5 (3)	8 (2)	2171-1028	712
1183.4 (1)	7.2 (1.8)	2064- 880	
1229.07 (7)	33 (3)	2109- 880	220, 273, 292, 434, 880
1232.3 (2)	16 (2)	1891- 659	344
1247.86 (4)	66 (3)	1997- 749	89, 314, 344, 434
1249.3 (4)	2 (2)	1997- 748	
1259.99 (3)	62 (3)	2311-1051	171, 273, 463, 1051
1272.72 (3)	39 (3)	2022- 749	89, 273, 344, 434
1276.0 (1)	1.4 (6)	2327-1051	
1290.99 (4)	37 (3)	2171- 880	220, 273, 292, 344, 880
1303.25 (3)	1000 (20)	1891- 588	273, 419, 454
1314.68 (7)	32 (3)	2064- 749	89, 344, 434
1316.0 (4)	2 (2)	2064- 748	748
1317.5 (4)	1 (1)	2345-1028	
1337.54 (3)	88 (6)	1997- 659	(314), 344
1362.40 (8)	13 (2)	2022- 659	
1404.4 (1)	6.6 (1.6)	2064- 659	
1408.71 (3)	70 (3)	1997- 588	273, (314)
1422.21 (7)	19 (2)	2171- 749	89, 273, 344, 434
1430.97 (5)	53 (3)	2311- 880	220, 273, 292, 880
1433.5 (2)	6 (4)	2022- 588	
1450.0 (1)	34 (3)	2109- 659	273, 344
1468.9 (2)	2.1 (6)	1468- 0	
1475.4 (1)	23 (2)	2064- 588	273
1511.9 (2)	3.7 (1.8)	2171- 659	
1521.0 (2)	4.8 (1.6)	2109- 588	
1562.20 (4)	78 (3)	2311- 749	89, 273, 344, 434
1563.6 (4)	4 (2)	2311- 748	
1576.59 (3)	610 (11)	1891- 315	105, 279, 419, 453
1578.4 (3)	8.0 (2.5)	2327- 749	
1583.1 (1)	2.9 (1.3)	2171- 588	
1596.0 (4)	2 (2)	2345- 749	

TABLE I. *(Continued)*

Energy [a] (keV)	Relative intensity [a,b]	Placement [c] (keV)	Coincident γ rays observed [d] (keV)
1597.3 (4)	2.4 (2.0)	2345– 748	
1652.1 (2)	16 (6)	2311– 659	273, 344
1682.02 (7)	38 (3)	1997– 315	
1685.8 (3)	2.1 (0.8)	2345– 659	
1706.88 (5)	54 (3)	2022– 315	
1723.03 (3)	109 (4)	2311– 588	273
1739.1 (1)	6.9 (1.8)	2327– 588	
1748.8 (2)	4.5 (1.8)	2064– 315	
1756.8 (2)	2.4 (1.1)	2345– 588	
1856.4 (1)	14 (2)	2171– 315	
1867.3 (1)	5.8 (1.6)	2455– 588	273
2012.5 (1)	5.9 (1.2)	2327– 315	
2030.1 (1)	3.5 (1.0)	2345– 315	

[a] Value shown as 71.12 (2), for example, means 71.12 ± 0.02.
[b] The intensity values for ^{117}Cd^{g} decay are relative to a value of 1000 for the 1303.25-keV transition. To convert to absolute intensity (per 100 β decays), multiply the relative intensity by 0.0187.
[c] Assignments are made on the basis of energy sums and coincidence relationships.
[d] Coincidences in parentheses are marginal.
[e] Denotes unresolved multiplet with individual intensities as determined from coincidence data.

for the ^{116}Cd $(n_{th}, \gamma)^{117}$Cd^{m} reaction. These values, particularly the latter, are not in good agreement with the published values[14] of 50 mb and 25 mb, respectively. The differences are doubtless a consequence of the similar half-lives of the two isomers and the incorrect decay schemes used in calculating previous cross sections from measurements.

III. THE DECAY SCHEME

A. Level and γ-ray assignments

In Figs. 1 and 2 we show the decay schemes for 2.5-h ^{117}Cd^{g} and 3.4-h ^{117}Cd^{m}, respectively, to the levels of ^{117}In. The log ft values were computed using our γ-ray intensities, the Q values deduced from reaction studies,[15,16] and the log f tables of Gove and Martin.[17]

It may be seen that our decay scheme for ^{117}Cd^{g} is in relatively good agreement with that proposed by Gregory and Johns[7] and our decay scheme for ^{117}Cd^{m} is in relatively good agreement with the work of Tang *et al.*[6] We have observed several new levels in ^{117}Cd^{g} decay not proposed by Gregory and Johns,[7] including levels involving the γ rays they used to assign levels at 862 and 1360 keV. Our ^{117}Cd^{m} decay scheme differs with that of Tang *et al.*[6] by our lack of a level at 2229 keV and by inclusion of a tentative level at 1855 keV. Both our work and the work of Tang *et al.*[6] include levels at 1957, 2096, 2440, 2462, 2476, and 2540 keV not shown by Gregory and Johns.[7]

We have noted in Figs. 1 and 2 the levels populated in (^{3}He, d) reactions[18,19] and (d, ^{3}He) reactions.[16] The most sensitive (^{3}He, d) studies are those of Harar and Horoshko[18] which have an energy uncertainty of ±15 keV. They show a sequence of levels at 1360, 1603, 1696, 1774, 1883, 2005, 2047, and 2159 keV that are 9 to 17 keV below the levels we observe at 1376, 1609–1612, 1712, 1784, 1891, 2022, 2064, and 2171 keV, respectively. We have assumed these to be the same levels.

B. Spin and parity assignments

The spin and parity assignments we show in Figs. 1 and 2 were deduced by combining the existing results from (d, ^{3}He) and (^{3}He, d) studies[16,18,19], lifetime studies,[20] and In level systematics[4,5,21,22] with our new γ-ray anisotropy values.[12,23,24] With the exception of the 748-keV level, the spins and parities of the levels below 1065 keV were established in earlier studies.[6,7,16,18] The tentative $\frac{7}{2}^{+}$ assignment for the 748-keV level is confirmed by our data, which shows γ-ray feeding from both $\frac{3}{2}^{+}$ (1712 keV) and $\frac{9}{2}^{-}$ (1957 keV) levels.

The 1554-keV level is limited to spin and parity of $\frac{1}{2}^{-}$ or $\frac{3}{2}^{-}$ by the $l=1$ transition populating this level in the (d, ^{3}He) study.[16] The $l=2$ (^{3}He, d) transitions[18] to the levels at 1376, 1609, (or 1612), 1712, and 1784 keV limit their spins and parities to $\frac{3}{2}^{+}$ and $\frac{5}{2}^{+}$. Because the 1609-keV level feeds the

TABLE II. γ rays observed in the decay of 3.4-h $^{117}Cd^{m}$.

Energy [a] (keV)	Relative intensity [a,b]	Placement [c] (keV)	Coincident γ rays observed [d] (keV)
71.12 (2)	0.2 [e]	659- 588	
89.73 (1)	0.03 [e]	749- 659	
97.71 (5)	46 (5)	2095-1997	366, 564, 631, 762, 1065, 1432, 1997
99.4 (1)	5 (2)	2096-1997	
101.0 (2)	3 (2)	2540-2440	
131.4 (2)	0.1 [e]	880- 749	
132.7 (1)	0.2 [e]	880- 748	
160.8 (4)	0.002 [e]	749- 588	
168.65 (6)	13 (2)	1234-1065	762, 860, 1065
171.05 (7)	0.01 [e]	1051- 880	
220.95 (4)	10 (6)	880- 659	484, 631
273.36 (2)	13 [e]	588- 315	
292.06 (4)	5 (5)	880- 588	484, 631
299.5 (1)	20 (3)	1365-1065	
310.3 (1)	22 (4)	2405-2095	860, 1029, 1065, 1234
313.8 (4)	<1 (1)	1365-1051	
315.3 (2)	I. T.	315- 0	
325.4 (2)	6 (2)	2322-1997	
344.46 (1)	9.8 [e]	659- 315	
366.92 (5)	145 (10)	1432-1065	97, 564, 663, 1065
381.2 (4)	<1 (1)	1432-1051	
408.0 (2)	3.8 (2.0)	2405-1997	
434.19 (2)	0.07 [e]	749- 315	
439.4 (1)	8 (3)	1028- 588	929
460.95 (4)	71 (6)	1209- 748	748, 788, 886, 1196, 1208
463.04 (3)	0.4 [e]	1051- 588	
484.79 (3)	44 (5)	1365- 880	220, 292, 631, 880, 957
518.8 (3)	2.5 (1.2)	2476-1957	
545.0 (4)	7 (3)	2400-1855	
564.39 (2)	640 (27)	1997-1432	97, 366, 1065, 1432
617.48 (9)	15 (3)	1365- 748	
631.79 (6)	122 (8)	1997-1365	97, 220, 299, 484, 617, 748, 880, 1065, 1365
663.52 (7)	30 (3)	2096-1432	366, 1065, 1432
684.6 (4)	2.9 (1.6)	1432- 748	
712.71 (6)	44 (6)	1028- 315	(545), 827, 929
748.05 (4)	155 (15)	748- 0	460, 564, 617, 631, 684, 788, 886, 1196, 1209, 1652, 1669
762.73 (5)	75 (5)	1997-1234	168, 273, 1065, 1234
788.2 (1)	22 (4)	1997-1209	
827.6 (1)	12 (3)	1855-1028	
860.40 (4)	343 (12)	2095-1234	310, 1234
880.71 (2)	31 (12)	880- 0	484, 631
886.0 (1)	17 (3)	2095-1209	
929.3 (1)	34 (5)	1957-1028	
931.36 (5)	159 (10)	1997-1065	1065
957.3 (1)	17 (4)	2322-1365	
1029.06 (3)	507 (15)	2095-1065	310, 1065
1051.7 (1)	1.6 [e]	1051- 0	(313), (381)
1065.98 (3)	1000 (25)	1065- 0	168, 299, 310, 366, 564, 860, 931, 1029, 1257, 1339
1170.7 (1)	28 (5)	2405-1234	
1196.2 (1)	17 (4)	2405-1209	
1205.5 (3)	5.7 (1.6)	2440-1234	
1208.3 [f] (4)	2 (3)	2417-1209	
1209.0 [f] (4)	8 (3)	1209- 0	
1209.0 [f] (4)	6 (3)	1957- 748	
1234.59 (3)	479 (13)	1234- 0	310, 762, 860, 1170, 1205
1257.0 (2)	8.6 (3.2)	2322-1065	

TABLE II. *(Continued)*

Energy [a] (keV)	Relative intensity [a,b]	Placement [c] (keV)	Coincident γ rays observed [d] (keV)
1339.30 (5)	90 (10)	2405–1065	1065
1365.51 (8)	72 (4)	1365– 0	631, 957
1432.90 (3)	585 (13)	1432– 0	97, 564, 663
1652.1 (1)	20 (4)	2400– 748	748
1669.3 (1)	27 (3)	2417– 748	748
1957.5 (2)	6.8 (1.7)	1957– 0	
1997.34 (3)	1140 (20)	1997– 0	97, 325, 408
2096.40 (5)	324 (7)	2096– 0	
2322.80 (5)	342 (7)	2322– 0	
2400.2 (2)	33 (2)	2400– 0	
2414.2 (2)	3 (3)	2414– 0	
2417.3 (1)	44 (2)	2417– 0	
2462.8 (2)	9.2 (1.0)	2462– 0	
2476.2 (2)	8.1 (8)	2476– 0	
2540.8 (3)	6.5 (8)	2540– 0	

[a] Value shown as 71.12 (2), for example, means 71.12 ± 0.02.
[b] The intensity values for $^{117}Cd^{m}$ decay are relative to a value of 1000 for the 1065.98-keV transition. To convert to absolute intensity (per 100 β decays), multiply the relative intensity value by 0.023.
[c] Assignments are made on the basis of energy sums and coincidence relationships.
[d] Coincidences in parentheses are marginal.
[e] Intensity required to balance transition strengths.
[f] Denotes unresolved multiplet with individual intensities as determined from coincidence data.

$\frac{7}{2}^+$ level at 748 keV, it must be $\frac{3}{2}^+$. The deduced log *ft* values for the 1376-, 1712-, and 1784-keV levels are too low to be second forbidden transitions.[25] Thus, these levels are restricted to $\frac{3}{2}^+$ spin and parity assignments.

Of the remaining levels populated by $^{117}Cd^{g}$ decay, the eleven above 1800 keV are fed by allowed β transitions and must have spin and parity $\frac{1}{2}^+$ or $\frac{3}{2}^+$. Assignments of $\frac{1}{2}^+$ for the 1891-keV level and $\frac{3}{2}^+$ for the 2022-, 2064, and 2171-keV levels are established by the $l=0$ and $l=2$ transitions observed, respectively, in the (^{3}He, d) reaction.[18] The γ-ray transitions from the levels at 1997.34, 2311, and 2345 keV to the $\frac{7}{2}^+$ level at 748 keV verify $\frac{3}{2}^+$ assignments for these levels.

Since transitions into the $\frac{3}{2}^-$ (588 keV) level from positive-parity levels are $E1$ transitions with little possible $M2$ admixture, all of the $\frac{1}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$ cascades listed in Table III are required to have the same value of A_{22}. The large positive A_{22} values for the 1303-273, 1739-273, and 1867-273 cascades are observed to be in agreement with the assignments of $\frac{1}{2}^+$ for the 1891-, 2327-, and 2455-keV levels, respectively.

The large negative A_{22} values for the five $\frac{3}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$ cascades involving the 273-kev transition are consistent with the $\frac{3}{2}^+$ assignments previously identified for the 659-, 1997.34-, 2064-, and 2311-keV levels, and permit assigning $\frac{3}{2}^+$ as the spin and parity for the 2109-keV level. The 292-273 and 1463-273 cascades from the 880- and 1051-keV levels, respectively, have small positive anisotropies and are known to be $\frac{5}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$ cascades.

Figure 3 shows the values of A_{22} plotted against δ for cascades into the 588-keV level. Using the average value of A_{22} determined for all cascades involving the 273-keV transition, the value of δ can be deduced. Two values are observed to be consistent with the data; these are $\delta(273) = -0.10 \pm 0.02$ and -1.40 ± 0.04.

The placement of the 1468-keV level in the $^{117}Cd^{g}$ decay scheme is based on the weak 644-keV transition whose half-life is consistent with the decay of 2.5-h $^{117}Cd^{g}$. The $\frac{7}{2}^+$ assignment is quite speculative and is based on the possible weak γ-ray feeding from the levels strongly populated in the decay of $^{117}Cd^{m}$. Given this tentative assignment for the 1468-keV level, the level at 2112 keV becomes a $\frac{3}{2}^+$. The level at 1439 keV is placed on the basis of the observed 850-273 coincidence. The log*ft* is consistent with negative parity.

In the decay of $^{117}Cd^{m}$ ($\frac{11}{2}^-$), the level at 1432 keV is assigned to be a $\frac{9}{2}^+$ on the basis of the $l=4$ transition in the (d, ^{3}He) reaction[16] and a nonunique first forbidden β transition from $^{117}Cd^{m}$. The level at 1365 keV is also assigned a spin and parity of $\frac{9}{2}^+$ on the basis of a nonunique first forbidden β decay and a strong γ ray to the $\frac{5}{2}^+$ (880

TABLE III. Results of the $^{117}Cd^{m,g}$ angular correlation measurements.

Cascade (keV)	Measured[a] A_{22}	Spin sequence	Mixing ratio[a]	%$E2$	Theoretical A_{22}
588-keV level					
1303– 273	+0.326 (9)	$\frac{1}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
1739– 273	+0.30 (18)	$\frac{1}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
1867– 273	+0.13 (18)	$\frac{1}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
71– 273	−0.27 (7)	$\frac{3}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$	$\delta(273) = -0.10$ (2)	0– 5	
1408– 273	−0.27 (4)	$\frac{3}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$	−1.40 (4)	53– 79	
1475– 273	−0.28 (8)	$\frac{3}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
1521– 273	−0.15 (18)	$\frac{3}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
1723– 273	−0.20 (3)	$\frac{3}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
292– 273	+0.09 (4)	$\frac{5}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
463– 273	+0.10 (4)	$\frac{5}{2}^+(1)\frac{3}{2}^-(1,2)\frac{1}{2}^-$			
749-keV level					
862– 434	−0.01 (10)	$\frac{1}{2}^+$ intermediate state			0.0
963– 434	+0.07 (10)	$\frac{1}{2}^+$ intermediate state			0.0
1142– 434	+0.02 (6)	$\frac{1}{2}^+$ intermediate state			0.0
1247– 434	+0.00 (7)	$\frac{1}{2}^+$ intermediate state			0.0
1272– 434	−0.01 (10)	$\frac{1}{2}^+$ intermediate state			0.0
1314– 434	−0.05 (13)	$\frac{1}{2}^+$ intermediate state			0.0
1422– 434	+0.03 (14)	$\frac{1}{2}^+$ intermediate state			0.0
1562– 434	+0.05 (6)	$\frac{1}{2}^+$ intermediate state			0.0
880-keV level					
831– 292	+0.25 (7)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1)\frac{3}{2}^-$	$\delta(831) = +0.14$ (9)	0– 5	
831– 880	−0.09 (4)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$	+2.4 (9, 6)	76– 91	
1116– 292	+0.23 (14)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1)\frac{3}{2}^-$	$\delta(1116) = +0.1$ (3, 2)	0– 14	
1116– 880	−0.20[b] (8)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$	+2 (2, 1)	78– 92	
1229– 292	+0.01 (14)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1)\frac{3}{2}^-$	$\delta(1229) = -0.2$ (2)	0– 12	
1229– 880	−0.33[b] (11)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$	~10	97–100	
1290– 292	+0.22 (16)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1)\frac{3}{2}^-$	$\delta(1290) = +0.1$ (2, 8)	0– 32	
1290– 880	−0.19[b] (10)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$	+2.7 (2.5, 1.2)	69– 96	
1430– 292	+0.23 (14)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1)\frac{3}{2}^-$	$\delta(1430) = +0.1$ (2, 7)	0– 32	
1430– 880	−0.18[b] (9)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$	+2.7 (2.5, 1.2)	69– 96	
831– 220	+0.02[b] (4)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1,2)\frac{3}{2}^+$			
1116– 220	+0.28[b] (7)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1,2)\frac{3}{2}^+$			
1229– 220	+0.19[b] (12)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1,2)\frac{3}{2}^+$			
1290– 220	+0.08[b] (11)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1,2)\frac{3}{2}^+$			
1430– 220	+0.56[b] (11)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(1,2)\frac{3}{2}^+$			
1028-keV level					
969– 712	−0.16 (8)	$\frac{3}{2}^+(1)\frac{5}{2}^-(2)\frac{1}{2}^-$			−0.2
1143– 712	−0.1 (2)	$\frac{3}{2}^+(1)\frac{5}{2}^-(2)\frac{1}{2}^-$			−0.2

TABLE III. *(Continued)*

Cascade (keV)	Measured[a] A_{22}	Spin sequence	Mixing ratio[a]	%$E2$	Theoretical A_{22}
1051-keV level					
840-1051	+0.06[b] (7)	$\frac{1}{2}^+(2)\frac{5}{2}^+(2)\frac{9}{2}^+$			+0.102
945-1051	+0.15[b] (6)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$			
1120-1051	+0.15[b] (19)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$			
1259-1051	+0.17[b] (8)	$\frac{3}{2}^+(1,2)\frac{5}{2}^+(2)\frac{9}{2}^+$			
1065-keV level					
366-1065	−0.11[b] (6)	$\frac{9}{2}^+(1,2)\frac{11}{2}^+(1,2)\frac{9}{2}^+$			
		$[\frac{9}{2}^+(2)\frac{13}{2}^+(2)\frac{9}{2}^+]$			[+0.195]
931-1065	+0.09 (8)	$\frac{11}{2}^-(1)\frac{11}{2}^+(1,2)\frac{9}{2}^+$			
1029-1065	−0.07 (5)	$\frac{13}{2}^-(1)\frac{11}{2}^+(1,2)\frac{9}{2}^+$	$\delta(1065)=+0.3$ (2, 1)	1– 20	
1339-1065	−0.1 (1)	$\frac{13}{2}^-(1)\frac{11}{2}^+(1,2)\frac{9}{2}^+$	+6 (11, 3)	90–100	
1234-keV level					
762-1234	−0.01 (12)	$\frac{11}{2}^-(1)\frac{13}{2}^+(2)\frac{9}{2}^+$			−0.110
860-1234	+0.13 (5)	$\frac{13}{2}^-(1)\frac{13}{2}^+(2)\frac{9}{2}^+$			+0.176
1365-keV level					
631- 484	−0.08 (10)	$\frac{11}{2}^-(1)\frac{9}{2}^+(2)\frac{5}{2}^+$			−0.071
		$[\frac{9}{2}^-(1)\frac{9}{2}^+(2)\frac{5}{2}^+]$			[+0.190]
1432-keV level					
564- 366	+0.06 (4)	$\frac{11}{2}^-(1)\frac{9}{2}^+(1,2)\frac{11}{2}^+$	$\delta(366)=+0.15$ (20)	0– 11	
			~15	97–100	
564-1432	+0.09 (4)	$\frac{11}{2}^-(1)\frac{9}{2}^+(1,2)\frac{9}{2}^+$	$\delta(1432)=-3$ (2, 20)	50–100	
663-1432	−0.16 (22)	$\frac{9}{2}^-(1)\frac{9}{2}^+(1,2)\frac{9}{2}^+$			
1612-keV level					
497- 862	+0.26 (18)	$\frac{3}{2}^+(1,2)\frac{3}{2}^+(1,2)\frac{1}{2}^+$			
		$[\frac{3}{2}^+(1,2)\frac{1}{2}^+(1,2)\frac{1}{2}^+]$			[0.0]
1997(*m*)-keV level					
97-1997	+0.33 (29)	$\frac{13}{2}^-(1,2)\frac{11}{2}^-(1)\frac{9}{2}^+$			

[a] The numbers in parentheses represent uncertainties in the last digits. For example, the measured A_{22} which reads +0.326 (9) means $A_{22}=+0.326\pm0.009$.

[b] The indicated spin sequence does not exclude the possibility of a small A_{44} contribution, thus, the anisotropy cannot be directly equated with A_{22}. Where two numbers are listed in parentheses, the first indicates the uncertainty in the last digits below the listed value. Thus, +2.4 (9, 6) indicates $+2.4^{+0.9}_{-0.6}$.

keV) level.

Nonunique first forbidden or allowed β decay to the 1957-keV level establishes a minimum spin of $\frac{9}{2}$ for that level.[25] The succeeding 929-712 cascade through the 1028-keV intermediate level to the $\frac{1}{2}^-$ level at 315 keV is not possible unless the 1957- and 1028-keV levels are $\frac{9}{2}^-$ and $\frac{5}{2}^-$, respectively. The 1855-keV level decays to the $\frac{5}{2}^-$ level at 1028 keV and must be either $\frac{7}{2}^-$ or $\frac{9}{2}^-$.

Ten of the twelve levels above 1960 keV are populated by allowed β decay (2414 and 2440 keV being the exceptions), hence, they are required to be $\frac{9}{2}^-$, $\frac{11}{2}^-$, or $\frac{13}{2}^-$. The existence of transitions to the $\frac{7}{2}^+$ level forces a $\frac{9}{2}^-$ assignment for both the 2400- and 2417-keV levels. The strong γ-ray transition from the negative parity 1997.31-keV level to the $\frac{9}{2}^+$ ground state restricts the possible assignments to $\frac{9}{2}^-$ and $\frac{11}{2}^-$. The $\frac{11}{2}^-$ assignment is favored by the measured value of the anisotropy ($A_{22}=-0.08\pm0.10$) for the 631-481 cascade which is consistent with the theoretical value of −0.071 for a $\frac{11}{2}^-(1)\frac{9}{2}^+(2)\frac{5}{2}^+$ cascade but not

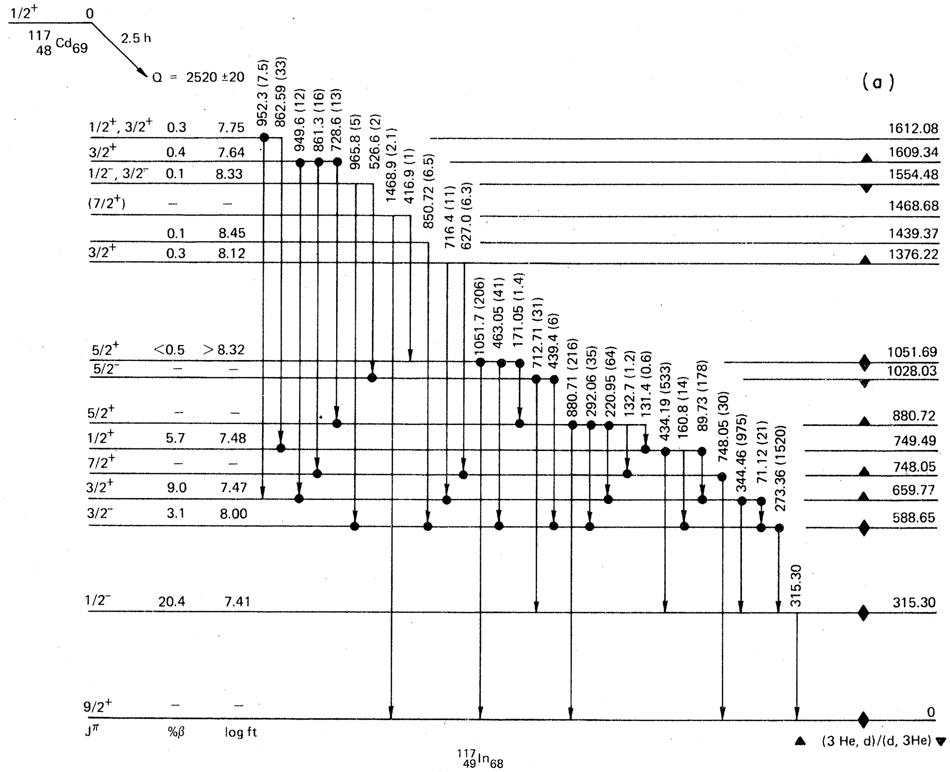


FIG. 1. Proposed decay scheme for 2.5-h ^{117}Cd^g. (a) 0–1650 keV, (b) 1650–2000 keV, (c) 2000–2150 keV, (d) 2150–2500 keV.

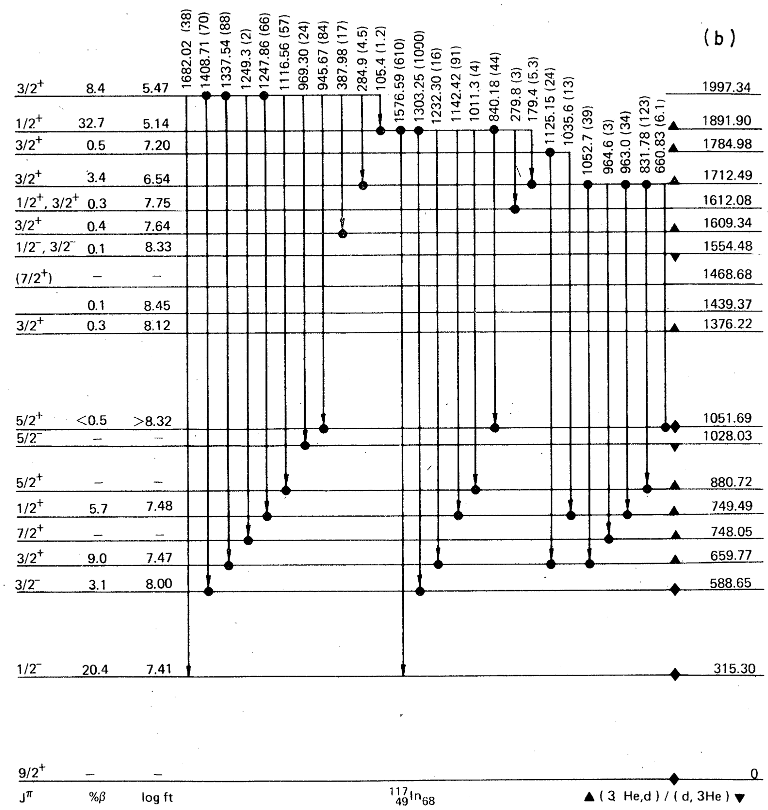
consistent with a theoretical value of +0.19 for a $\frac{9}{2}^-(1)\frac{9}{2}^+(2)\frac{5}{2}^+$ cascade. The assignments for other high-lying levels are dependent on assignments for the levels between 1060 and 1440 keV.

The 1065-, 1209-, and 1234-keV levels observed in the decay of ^{117}Cd^m but not seen in the decay of ^{117}Cd^g must have relatively high spins. These levels are fed by transitions from the 1997.31-keV level ($\frac{11}{2}^-$) and depopulate to the $\frac{9}{2}^+$ ground state. Based on the presence of one $\frac{13}{2}^+$ and two $\frac{11}{2}^+$ states near 1200 keV in the systematics of the odd-mass In isotopes, we identify the levels at 1065, 1209, and 1234 keV as being the $\frac{11}{2}^+$, $\frac{11}{2}^+$, and $\frac{13}{2}^+$ states, respectively.

Although not totally conclusive, there is supportive evidence for the assignments to the 1065-, 1209-, and 1234-keV levels. The 1209-keV level cannot be $\frac{13}{2}^+$ because it feeds the $\frac{7}{2}^+$(748 keV) level. The 1065-keV level cannot be $\frac{13}{2}^+$ because the measured anisotropy value of -0.11 ± 0.06 for the 366-1065 cascade disagrees with the theoretical value of the anisotropy ($A_{22} = +0.195$) for $\frac{9}{2}^+(2)\frac{13}{2}^+(2)\frac{9}{2}^+$ cascades. A $\frac{13}{2}^+$ assignment for the 1234-keV level is consistent with the measured anisotropies for the 762-1234 and 860-1234 cascades. Additionally, the 1234-keV level has a decay pattern very similar to the decay pattern for the $\frac{13}{2}^+$ (1290 keV) level in ^{115}In. Different anisotropies for the 1029-1065 and 860-1234 cascades (as well as for the 931-1065 and 762-1234 cascades) support different assignments for the 1065- and 1234-keV levels.

The contrasting anisotropies for the cascades depopulating the 1997.31- and 2095-keV levels require the 2095-keV level to have a spin other than $\frac{11}{2}^-$. Since the 2095-keV level branches to the 1234-keV level, the 2095-keV level requires an assignment of $\frac{13}{2}^-$. With a $\frac{13}{2}^-$ assignment for the 2095-keV level, only $\frac{11}{2}^+$ assignments are possible for the 1065- and 1209-keV levels.

A $\frac{13}{2}^-$ assignment to the 2405-keV level is based on allowed β feeding, a decay pattern similar to the 2095-keV level, and a measured $A_{22} = -0.1 \pm 0.1$ for the 1339-1065 cascade which contrasts with the measured anisotropy of $+0.09 \pm 0.08$ for the 931-1065 cascade originating from the 1997.31-keV level. A $\frac{9}{2}^-$ assignment is proposed for the 2096-keV level by virtue of its allowed β feeding, a strong branch to the ground state (which excludes $\frac{13}{2}^-$), and a measured $A_{22} = -0.16 \pm 0.22$ for the 663-1432 cascade which is not like the measured $A_{22} = +0.09 \pm 0.04$ for the 564-1432 cascade from a known $\frac{11}{2}^-$ (1997.31 keV) level.



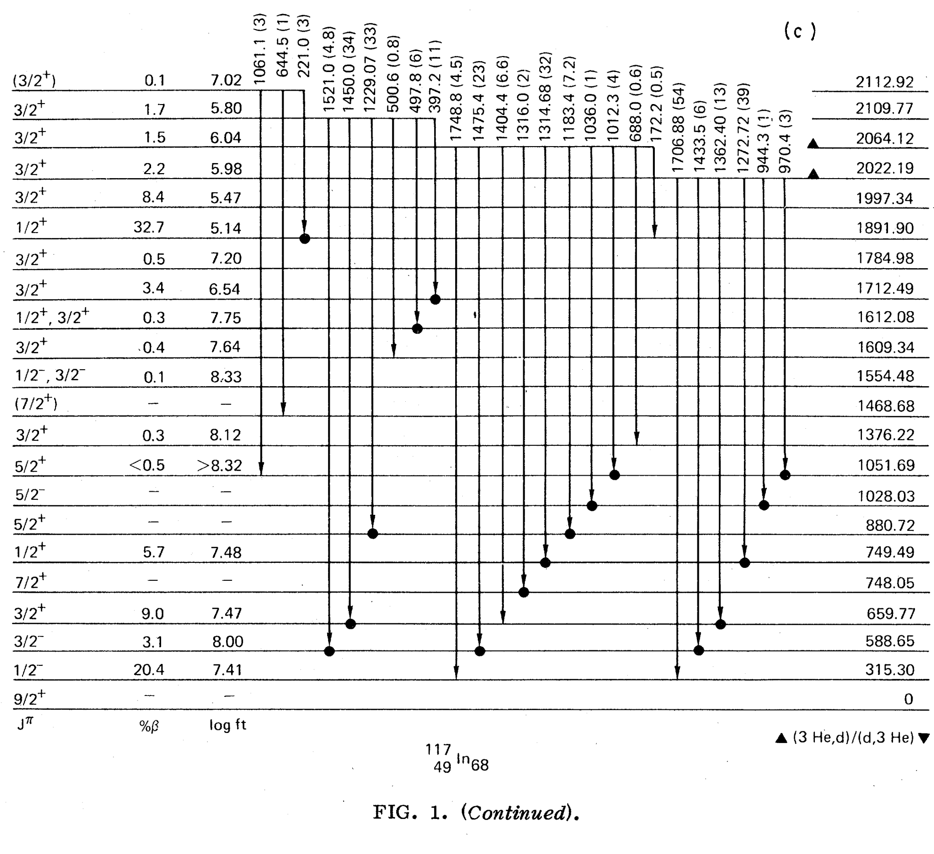


FIG. 1. (*Continued*).

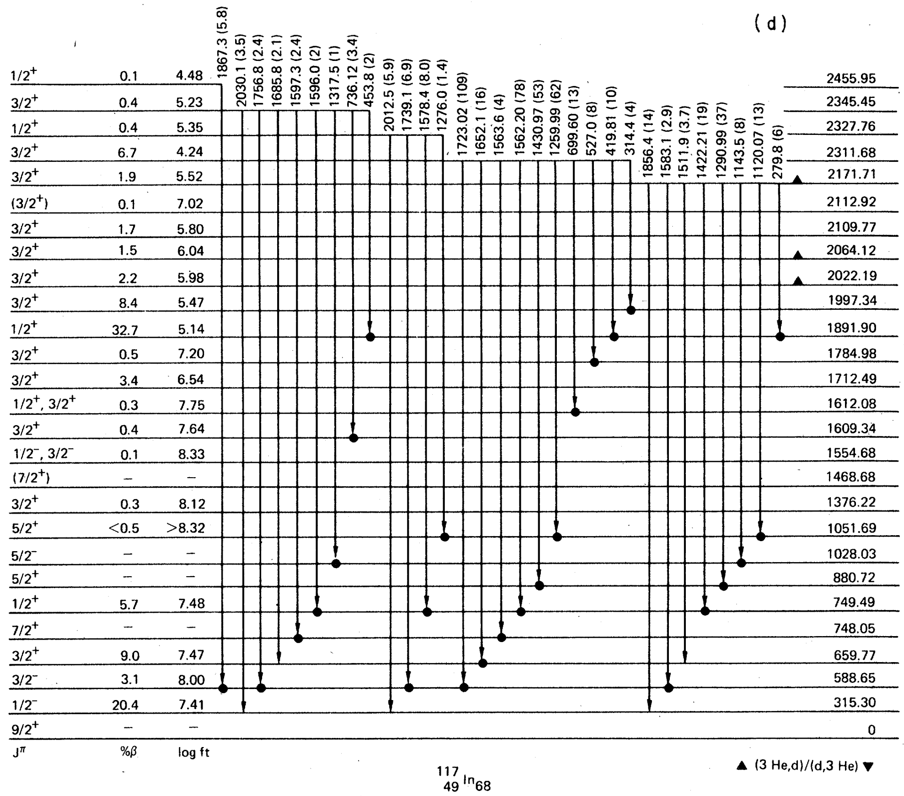


FIG. 1. (*Continued*).

IV. DISCUSSION

A. Comparison with unified model calculations

The character and quality of both the unified model and Nilsson model fits to the low-lying levels of ^{113}In and ^{115}In were discussed earlier.[1] Figure 4 shows the calculated unified model positive-parity states for ^{117}In. We note the same reasonable fits for the positions of the levels below 1500 keV as had been obtained for ^{113}In and ^{115}In. We also note the relatively high positions predicted for the $\frac{13}{2}^+$ and $\frac{15}{2}^+$ particle-hole states. A search for evidence of the $\frac{13}{2}^+$ and $\frac{15}{2}^+$ particle-hole levels was conducted by inspecting the coincidence gates for the 460- and 484-keV traditions which depopulate the $\frac{11}{2}^+$ and $\frac{9}{2}^+$ particle-hole levels at 1209 and 1365 keV, respectively. We could find no evidence for such levels and conclude that they must lie above 2 MeV where branchings to these levels from the $\frac{11}{2}^-$ and $\frac{13}{2}^-$ strongly populated in β decay must be small.

In Fig. 5 we have grouped the levels of ^{117}In according to their unified model classifications. Of particular interest are the four $\frac{3}{2}^+$ levels at 1376, 1609, 1712, and 1784 keV, and the $\frac{1}{2}^+$ or $\frac{3}{2}^+$ level at 1612 keV. These five levels are characterized by strong transitions to the lower-lying, particle-hole levels and *no observed transitions* to the $\frac{1}{2}^-$ and $\frac{3}{2}^-$ single-hole levels. They are observed with considerable $l=2$ strength in the (^{3}He, *d*) reaction and are weakly populated in β decay. In Fig. 4 we show four $\frac{3}{2}^+$ calculated states at 1820, 2010, 2280, and 2760 keV and a $\frac{1}{2}^+$ state at 1997 keV whose wave functions are predominantly particle-hole and are expected[1] to branch quite strongly to the lower-lying, particle-hole states. There is, therefore, considerable particle-hole $\frac{1}{2}^+$ and $\frac{3}{2}^+$ strength near 2 MeV to account qualitatively for the behavior of these five experimental levels. Furthermore, $\frac{3}{2}^+$ (or $\frac{1}{2}^+$) levels between 1300 and 1800 keV with small or unobserved $E1$ branches to the $p_{1/2}$ and $p_{3/2}$ single-particle states are not unique to ^{117}In. Three levels are observed in ^{119}In at 1624, 1770, and 1806 keV which decay exclusively to the lower-lying $\frac{1}{2}^+$, $\frac{3}{2}^+$, and $\frac{5}{2}^+$ levels. A number of levels have also been recently observed[26] in this same energy range (1602, 1607, 1676, 1736, 1759, and 1801 keV) by $(n, n'\gamma)$ studies of ^{115}In, and some of these may also show highly retarded $E1$ branches.

There are three additional levels at 2022, 2064, and 2109 keV which have been observed in (^{3}He, *d*) and exhibit strong transitions to the particle-hole levels. The decay of the 2109-keV level is par-

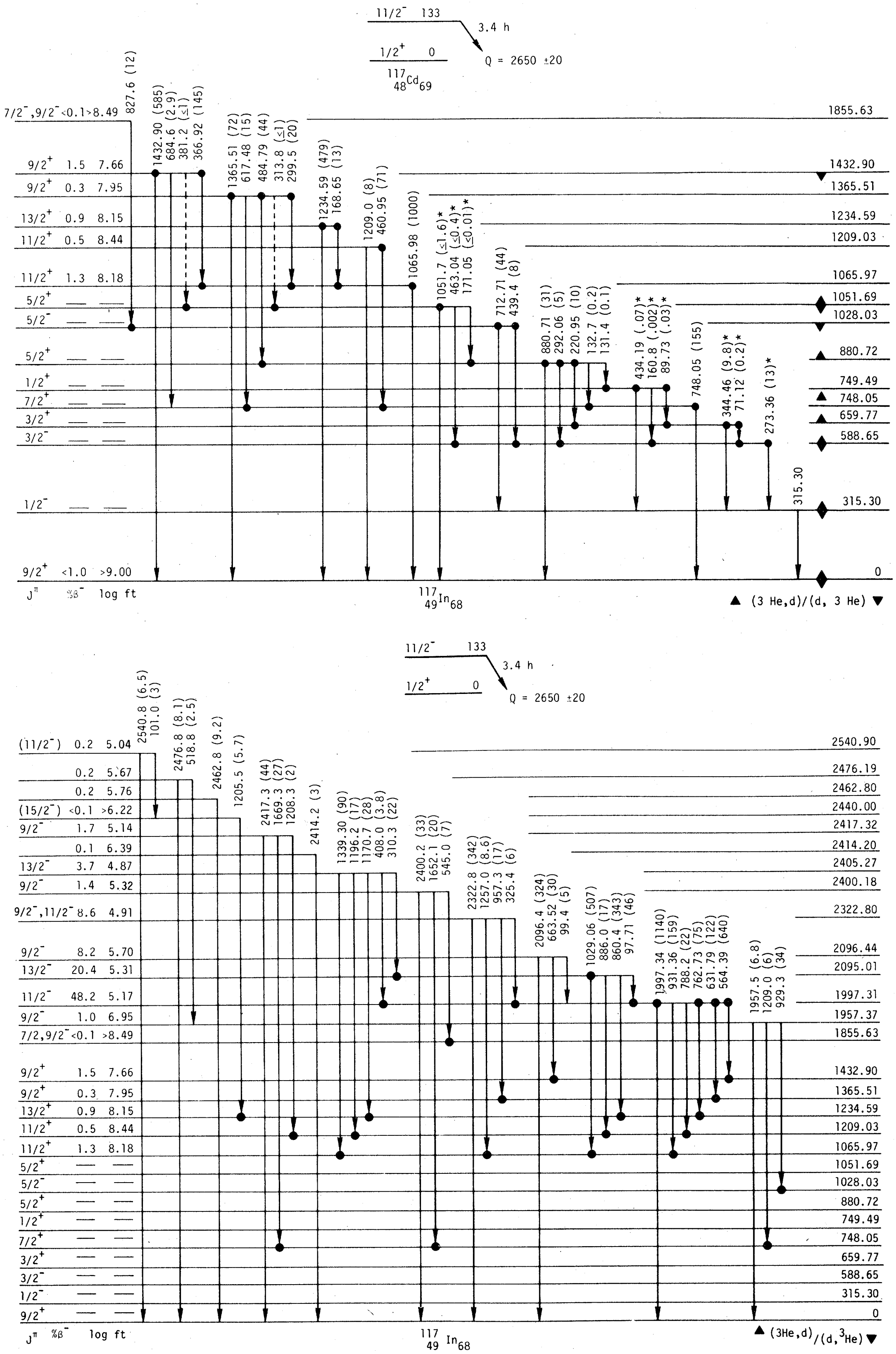


FIG. 2. Proposed decay scheme for 3.4-h $^{117}Cd^m$. (a) 0–1900 keV, (b) 1900–2600 keV.

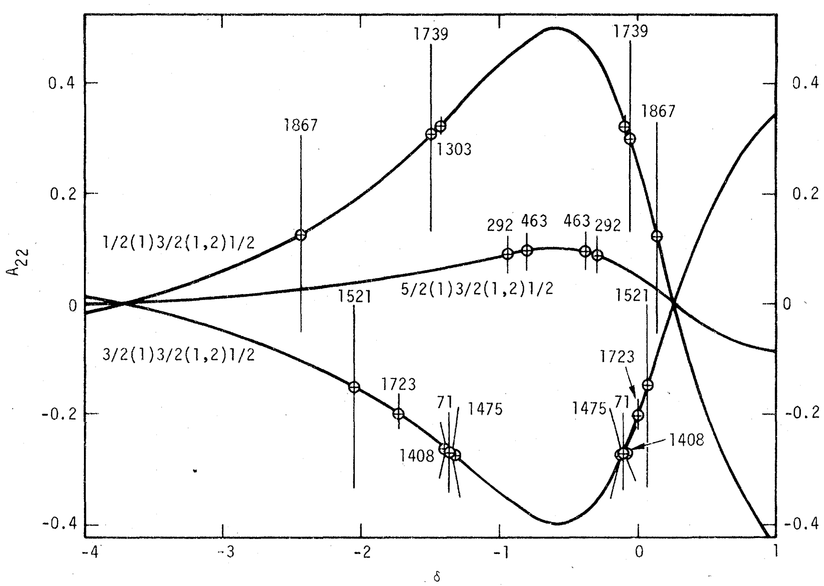


FIG. 3. A_{22} versus δ (273) for cascades involving the $\frac{3}{2}^-$ intermediate level at 588 keV.

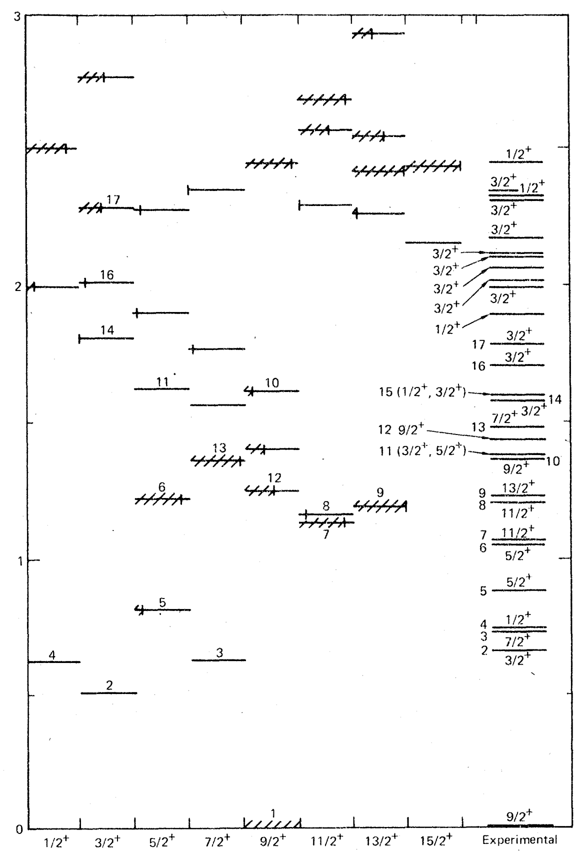


FIG. 4. Results of a unified model calculation for the states of ^{117}In. The cross-hatched portion of each level indicates that portion of the wave function coming from coupling the $g^{9/2}$, $p^{1/2}$, and $p^{3/2}$ states to the ^{118}Sn core in the unified model calculation. The remainder comes from particle-hole configurations.

ticularly interesting because its strongest transitions are to the particle-hole levels at 1612 and 1712 keV. Recent studies of the structure of ^{118}Sn by Bron *et al.*[27] have indicated the presence of a 2p-2h deformed band with members at 1757 (0^+), 2043 (2^+), and 2488 (4^+) keV. Figure 6 shows these three levels and their connecting transitions. We note the similarity of the log*ft* values for the 2488-keV level in ^{118}Sn and the 2109-keV level in ^{117}In.

The two negative-parity states at 1855 ($\frac{7}{2}^-$) and 1957 ($\frac{9}{2}^-$) keV show a preference for decay to the $\frac{5}{2}^-$ level at 1028 keV. As the $\frac{5}{2}^-$ level is expected to have a sizable $p_{1/2}{}^{-1}\otimes 2^+$ configuration admixture, the strong depopulating transitions suggest possible $p_{1/2}{}^{-1}\otimes 4^+$ configurations for both states.

B. Influence of one-proton-two-neutron configurations

There are few quantitative calculations for the character of the states resulting from the coupling of a proton hole with a seniority-two neutron state. In particular, the question of whether $\pi^{-1}\nu^2$ states involve a rather weak coupling of the proton to the ν^2 state, such that the proton is a mere spectator to transitions among the ν^2 multiplet, has not been resolved. (Alternatively, the proton could be interacting so strongly with the ν^2 state that little identity with the ν^2 spectrum could be observed.) As the unified model calculation fails to include the many $\pi^{-1}\nu^2$ states, the mixing of these states with particle-hole states cannot be discussed. However, there is little double that these configurations could be mixed in the 2 MeV region.

One approach to these questions is to compare the decay of ^{118}In to the levels of ^{118}Sn with the

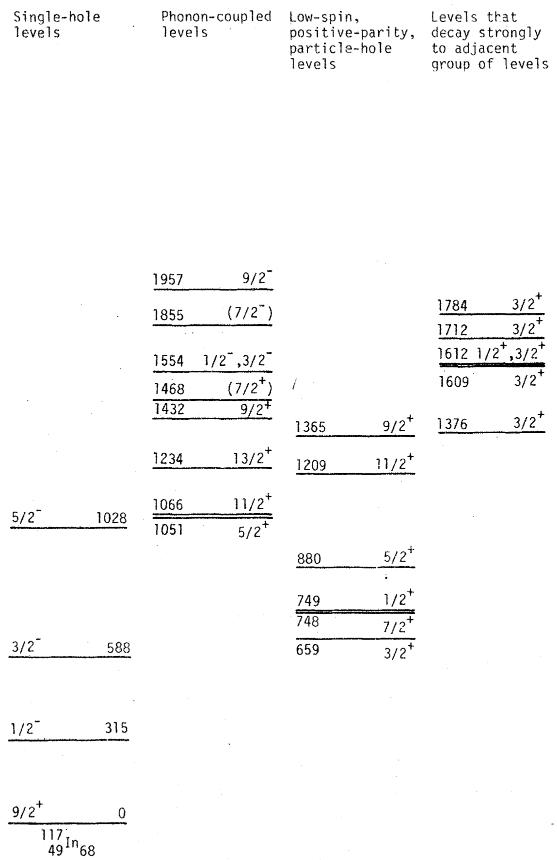


FIG. 5. Various groupings of ^{117}In levels according to their unified model classification.

decay of the ^{117}Cd isomers to ^{117}In. With few exceptions the levels above 1800 keV in ^{117}In are populated by allowed β decay from the respective $\frac{1}{2}^+$ or $\frac{11}{2}^-$ ^{117}Cd isomer. Since the single-particle $s_{1/2}$ and $h_{11/2}$ parent neutron states have no low-lying, single-particle states to which they can β decay, the only allowed β branches must be those involving the decay of a $g_{7/2}$ core neutron to the $g_{9/2}$ proton hole. In ^{117}Cd^g ($\frac{1}{2}^+$) this decay branch would involve the decay of a $[\nu s_{1/2}(\nu g_{7/2}\underline{\nu g_{7/2}})_{0^+}]_{1/2^+}$ state to a $\frac{1}{2}^+$ or $\frac{3}{2}^+$ state from the $[(\nu s_{1/2}\nu g_{7/2})_{3^+,4^+}\underline{\pi g_{9/2}}]_{1/2^+,3/2^+}$ configuration. Similarly, ^{117}Cd^m decays from a parent configuration of $[\nu h_{11/2}(\nu g_{7/2}\underline{\nu g_{7/2}})_{0^+}]_{11/2^-}$ to a daughter configuration $[(\nu h_{11/2}\nu g_{7/2})_{2^-,\ldots,9^-}\underline{\pi g_{9/2}}]_{9/2^-,11/2^-,13/2^-}$. Eight $\frac{9}{2}^-$, eight $\frac{11}{2}^-$, and eight $\frac{13}{2}^-$ daughter states can be constructed from such a configuration. The nucleus ^{118}In^m has the configuration $[(\pi g_{9/2}\nu s_{1/2})_{5^+}(\nu g_{7/2}\underline{\nu g_{7/2}})_{0^+}]_{5^+}$ which decays to the daughter configuration $[(\pi g_{9/2}\underline{\pi g_{9/2}})_{0^+}(\nu s_{1/2}\nu g_{7/2})_{4^+}]_{4^+}$ in ^{118}Sn. (The states involved in the β decay have been underlined and parentheses have been included to indicate the core states or those states which can be identified in the even-even nucleus.)

In Fig. 6 the experimental positive- and negative-parity levels, their log*ft* values, and their spins and parities are shown in the first and sixth columns, respectively. The levels denoted by an asterisk were described above and show highly hindered (unobserved) $E1$ branching to the low-lying $\frac{1}{2}^-$ and $\frac{3}{2}^-$ states. In the third column we show the observed levels of ^{118}Sn up to 2574 keV plus two additional 4^+ levels and log*ft* values for some levels fed in the decay of ^{118}Sb isomers (1^+ and 5^+). In the second column we show the zeroth order multiplets containing $\frac{1}{2}^+$ and $\frac{3}{2}^+$ states arising from the coupling of a $g_{9/2}$ hole to ^{118}Sn levels. In columns four and five we show the zeroth order negative-parity multiplets arising from the coupling of the $p_{1/2}$ and $g_{9/2}$ hole states, respectively, to the ^{118}Sn levels. The levels of ^{118}Sn have been studied extensively by Coulomb excitation, p-, d-, and α-inelastic scattering, and numerous reactions, in addition to the β decay of the 1^+, 5^+, and 8^- isomers of ^{118}In. Three β branches from ^{118}In^m (5^+) are observed and we have listed their log*ft* values on the 4^+ levels of ^{118}Sn. The $g_{9/2}$ proton hole can couple to each of these 4^+ states giving rise to a $\frac{1}{2}^+$ to $\frac{17}{2}^+$ multiplet. We identify two $\frac{1}{2}^+$ and $\frac{3}{2}^+$ pairs of states in ^{117}In with similar log*ft* values to the states in ^{118}Sn, which strongly indicates that these states have the $\pi^{-1}\nu^2$ configuration. Three levels (marked □) show strong decay branches to the particle-hole levels and other $\frac{3}{2}^+$ levels could be derived from the remaining 4^+ levels not strongly populated by the 5^+ parent, or by the $(\nu s_{1/2}\nu g_{7/2})_{3^+}$ state which cannot be fed by the decay of the ^{118}Sb 5^+ parent, or by the $\pi p_{3/2}\otimes 3^-$ configuration which lies above 3 MeV.

The negative-parity states are not as clearly identified with the ^{118}Sn core states. We do note, however, the existence of two $\frac{9}{2}^-$, $\frac{11}{2}^-$, and $\frac{13}{2}^-$ triplets of levels with each multiplet having similar log*ft* values that can be associated with the $g_{9/2}\otimes 3^-$ and $g_{9/2}\otimes 5^-$ configurations. The principal configuration of the 5^- and 7^- levels is thought to be $(\nu h_{11/2}\nu d_{3/2})_{4^-,\ldots,7^-}$ rather than the β-fed $(\nu h_{11/2}\nu g_{7/2})_{2^-,\ldots,9^-}$ configuration. Hence, the slightly larger log*ft* values for the decay to the negative-parity levels are to be expected.

These analyses can be interpreted as suggesting that the proton hole in ^{117}In is only weakly coupled to the ν^2 states in ^{118}Sn and that the proton plays a spectator role in the transitions between states that retain their ν^2 identity.

V. SUMMARY

We conclude that the structures observed in the odd-mass In isotopes up to the pairing energy can

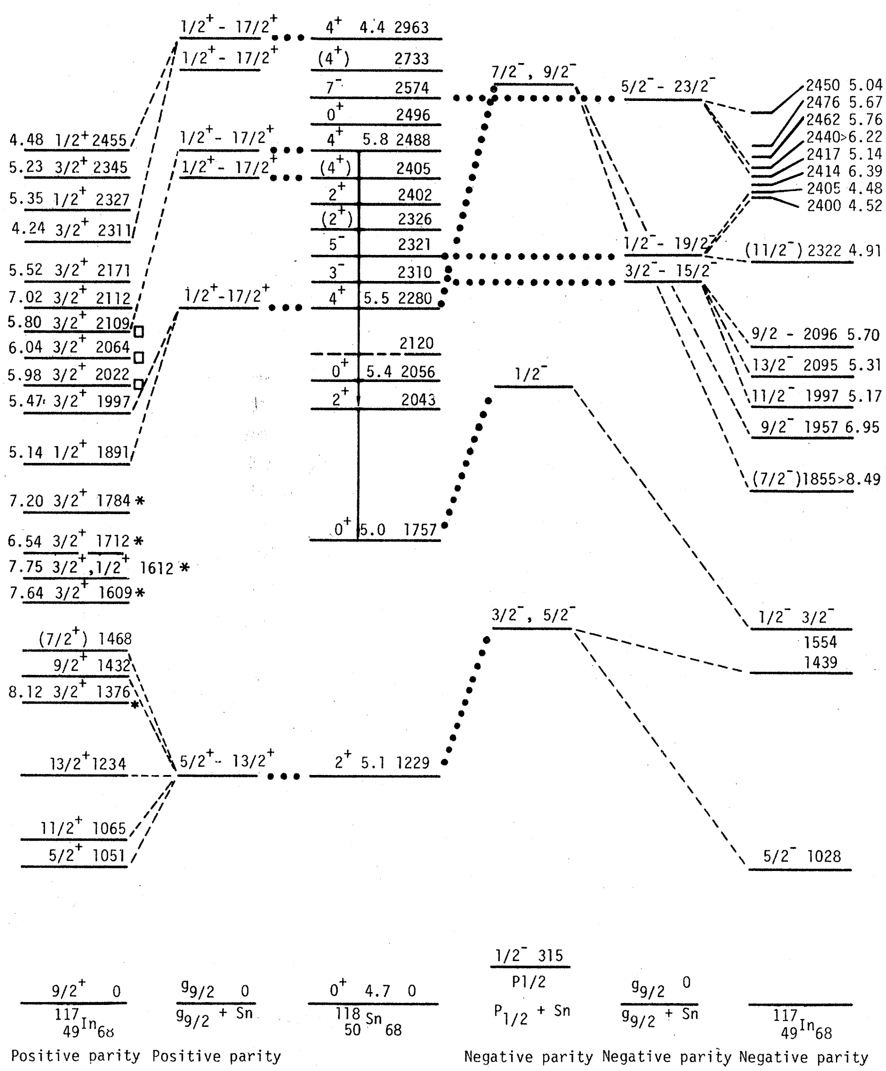


FIG. 6. Comparison of levels in ^{118}Sn with the positive- and negative-parity levels in ^{117}In.

be described almost quantitatively by the unified model calculations which permit both hole-core and particle-hole states to coexist (and mix to some extent) at low energies. Above the neutron pairing energy, we have observed $\pi^{-1}\nu^2$ levels with properties that indicate these levels are involved in the weak coupling of the proton hole to the ν^2 states in the ^{118}Sn core.

We wish to thank Dr. K. Heyde for his helpful discussions and the results of his unified model calculations.

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