PHYSICAL REVIEW C VOLUME 13, NUMBER 2 FEBRUARY 1976

Levels in the three-hole nucleus ^{105}Ag and the decay of 55.5-min ^{105}Cd†

S. V. Jackson*
Lawrence Livermore Laboratory, Livermore, California 94550
and Chemistry Department, University of Maryland, College Park, Maryland

W. B. Walters‡
Chemistry Department, University of Maryland, College Park, Maryland

R. A. Meyer
Lawrence Livermore Laboratory, Livermore, California 94550
(Received 8 September 1975)

The γ-ray spectrum following the decay of 55.5-min ^{105}Cd to levels of ^{105}Ag has been studied by singles, coincidence, and Compton-suppressed γ-ray spectroscopy. Sources were prepared by the $(n,2n)$ reaction on isotopically enriched ^{106}Cd sources using 14-MeV neutrons. A total of 274 γ rays are attributed to the decay of ^{105}Ag, and ~248 are placed in a level scheme involving 53 excited states. These data along with the results of (^{3}He,d) and (p,t) reaction studies were utilized to make spin and parity assignments for many of the levels. The systematics of the $Z=47$ silver nuclides are compared with various theoretical calculations and the systematics among the $N=58$ isotones are discussed.

[RADIOACTIVITY ^{105}Cd from ^{106}Cd $(n, 2n)$; measured E_γ, I_γ, $\gamma\gamma$ coin; ^{105}Ag deduced levels, $E_{\beta+}$, $I_{\beta+}$, I_{EC}, J, π. Enriched target, Ge(Li) detectors, Compton suppression.]

I. INTRODUCTION

The silver nuclei, with three holes in the proton-closed shell at $Z=50$, have recently been the subject of several theoretical calculations[1-8] concerned with three-hole states and their properties. These theoretical investigations have been particularly successful in describing the low-lying $\frac{7}{2}^+$ excited state (anomalous coupling state) that has been observed in the odd-mass silver isotopes from $A=103$ to $A=113$.[9] However, detailed theoretical calculations for other levels have been performed only for ^{107}Ag and ^{109}Ag. Recent experimental investigations have dealt primarily with the levels of ^{107}Ag and ^{109}Ag as observed in radioactive decay,[10,11] and in the ^{106,108}Pd (^{3}He, d) ^{107,109}Ag reactions.[3,12-14] These two nuclei, however, provide a somewhat limited check of the theoretical work because of the relatively low radioactive decay Q values involved. The large Q_β for the decay of $\frac{5}{2}^+$ and $\frac{11}{2}^-$ ^{111}Pd isomers has revealed a large number of levels with complex decay properties that are not easily understood.[11,15] The decay of $\frac{5}{2}^+$ ^{105}Cd to levels of ^{105}Ag is thus of interest because the large Q_{EC} value allows the observation of levels at higher excitation energies. In addition, knowledge of the levels of ^{105}Ag allows an extension of the odd-mass Ag systematics to a nucleus possessing a truer vibrational core than the heavier isotopes.

Studies of the decay of 55.5-min $\frac{5}{2}^+$ ^{105}Cd have thus far been limited to half-life determinations,[16-20] γ-ray singles measurements,[20-24] and a measurement of the conversion electrons from the 25.5-keV transition.[17] Two ^{105}Ag-level schemes have been proposed; however, the first[20] was not intended to establish the existence of any excited states but merely to illustrate the additive properties of the γ-ray energies, while the second[24] was inconsistent with γ-ray energy sums and intensity balances. When this investigation of the decay of ^{105}Cd was initiated, only one excited state of ^{105}Ag had been established, the $\frac{7}{2}^+$ 7.23-min isomeric state at 25.5 keV.[9] While this study was in progress, the results of a study of the excited states of ^{105}Ag as observed in the ^{107}Ag(p,t) reaction[25] and the ^{104}Pd(^{3}He, d) ^{105}Ag reaction were reported.[26]

We are reporting the results of a study on the γ rays in ^{105}Ag following the decay of ^{105}Cd in which 274 transitions have been identified with the 55.5-min half life and 248 transitions placed in a level scheme involving >53 levels. These data provide a basis for a systematic extension of the Ag ($Z=47$) isotopes and $N=58$ isotones as well as detailed comparisons with theoretical calculations.

II. EXPERIMENTAL PROCEDURE AND RESULTS

A. Source preparation

Two techniques were used to prepare ^{105}Cd sources. Initial studies utilized sources produced via the $^{106}Cd(\gamma, n)^{105}Cd$ reaction using bremsstrahlung from 30-MeV electrons accelerated by the National Bureau of Standards linear accelerator. However, these sources proved to be unsatisfactory for detailed spectroscopic studies owing to the presence of 56-min ^{104}Cd and its daughters 28-min $^{104}Ag^m$ and 68-min $^{104}Ag^g$. The sources produced by the $^{106}Cd(n, 2n)^{105}Cd$ reaction using 14-MeV neutrons were free of these activities and readily amenable to detailed study.

The samples of 55.5-min ^{105}Cd used in this study were produced via the $^{106}Cd(n, 2n)^{105}Cd$ reaction by irradiating 50–100 mg of enriched 82.09% ^{106}Cd as the oxide (purchased from Isotopes Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee) with 14-MeV neutrons from the Lawrence Livermore Laboratory (LLL) insulated core transformer (ICT) accelerator with rotating target neutron source (RTNS). This accelerator produces 14-MeV neutrons via the $^2H(^3H, \alpha)n$ reaction and can attain a maximum neutron flux of approximately $6\times10^{12} n/\text{sec}$ into 4π. It has been described in detail elsewhere.[27,28]

The enriched CdO target material was heat sealed in polyethylene capsules and transported to the RTNS using a pneumatic rapid sample transport system ("rabbit" system). Irradiation times ranged from approximately 10 min to 1 h, and the neutron flux at the target position was estimated to be approximately $1-5\times10^{10}\, n\, \text{cm}^{-2}/\text{sec}$. After irradiation, the samples were allowed to decay for 10–20 min to reduce the contributions from the contaminating activities, 122-sec ^{15}O, 7.1-sec ^{16}N, and 24.1-min $^{106}Ag^g$. No chemical separations were performed, and when counting began the principal activity present was 55.5-min ^{105}Cd. The following contaminating activities were readily identified on the basis of their unique γ-ray energies, intensities, and half-lives: 41-day $^{105}Ag^g$, 7.23-min $^{105}Ag^m$, 24.1-min $^{106}Ag^g$, 8.4-day $^{106}Ag^m$, 6.5-h ^{107}Cd, 48.6-min $^{111}Cd^m$, and 53.5-h $^{115}Cd^g$.[29–34] Five CdO targets were employed, and an irradiation was performed approximately every hour for 16 h for γ-ray singles spectroscopy and for 13 h for γ-γ coincidence spectroscopy.

B. γ-ray singles spectroscopy

Direct γ-ray spectra of 55.5-min ^{105}Cd samples were taken using the following detector pulse-height-analyzer systems at LLL: (1) the LLL Compton suppression spectrometer,[35] (2) a 50-cm^3 Ge(Li) detector having a full-width at half-maximum (FWHM) energy resolution of 1.6 keV at 1332 keV, (3) an 80-cm^3 Ge(Li) detector having FWHM energy resolution of 2.1 keV at 1332 keV, and (4) a 1.5-cm^3 Ge(Li) x-ray detector having a FWHM energy resolution of 500 eV at 60 keV. Source-to-detector distances ranged from ~35 cm to ~1 cm, and a 2.5-cm Pb absorber was used with the 80-cm^3 detector. The distance variations and the Pb absorber determined the summing contributions to the spectra. A new ^{105}Cd sample was produced every hour and the old sources moved on to the next detector-analyzer systems in sequence. In this manner a total of 16 1-h counts were summed on each of the systems. Contaminating activities could be identified on a half-life basis as each successive system counted the samples approximately one ^{105}Cd half-life (55.5 min) later than the preceding system. In addition, two of the samples were combined and then counted for ~12-h periods for eight days with the 80-cm^3 detector (without absorber) to aid in the identification of long-lived contaminant activities.

The γ-ray spectrum of the ^{105}Cd samples from 0–2.0 MeV as observed with the 50-cm^3 Ge(Li) detector is shown in Fig. 1. The high energy portion (2.0 to 2.8 MeV) of the γ-ray spectrum as observed through 2.5 cm of Pb with the 80-cm^3 Ge (Li) detector is shown in Fig. 2. A total of 250 peaks were observed to decay with a half-life of about 1 h, and were not single escape (SE), double escape (DE), x-ray escape, x ray, or sum peaks. Peak analysis was performed using the LLL spectrum analysis code GAMANAL,[36] and γ-ray energies were determined by counting sources simultaneously with numerous γ-ray standards and employing the precise energy values of Greenwood, Helmer, and Gehrke,[37,38] Nawrocki, Multhauf, and Tirsell,[39] and Meyer.[40]

The 250 peaks are tabulated in Table I along with 18 additional transitions that were established on the basis of γ-γ coincidence data and 11 transitions for which intensity limits were determined from either γ-ray singles or γ-γ coincidence spectra. Of these 279 transitions, five were assigned to the electron capture (EC) decay of 7.23-min $^{105}Ag^m$ on the basis of the coincidence data and the recent study of the EC-decay branch of $^{105}Ag^m$.[41] The remaining 274 transitions were assigned to the decay of 55.5-min ^{105}Cd, although 26 of these could not be placed in the decay scheme. Peak intensity corrections for contributions to the singles spectra from the decay of $^{105}Ag^g$ or $^{106}Ag^m$ were based on the recent decay scheme studies of these isomers.[42,43]

The absolute β^+/EC-decay branch of $\frac{5}{2}^+$ ^{105}Cd to the $\frac{7}{2}^+$ state at 25.5 keV in ^{105}Ag (7.23-min $\frac{7}{2}^+$ $^{105}Ag^m$) was determined to be $(51.4\pm4.0)\%$. A source of ^{105}Cd was produced in a short irradiation (10 min). The decay of the principal ^{105}Cd γ ray at 961.84 keV was followed for approximately two half-lives, and the activity at the end of irra-

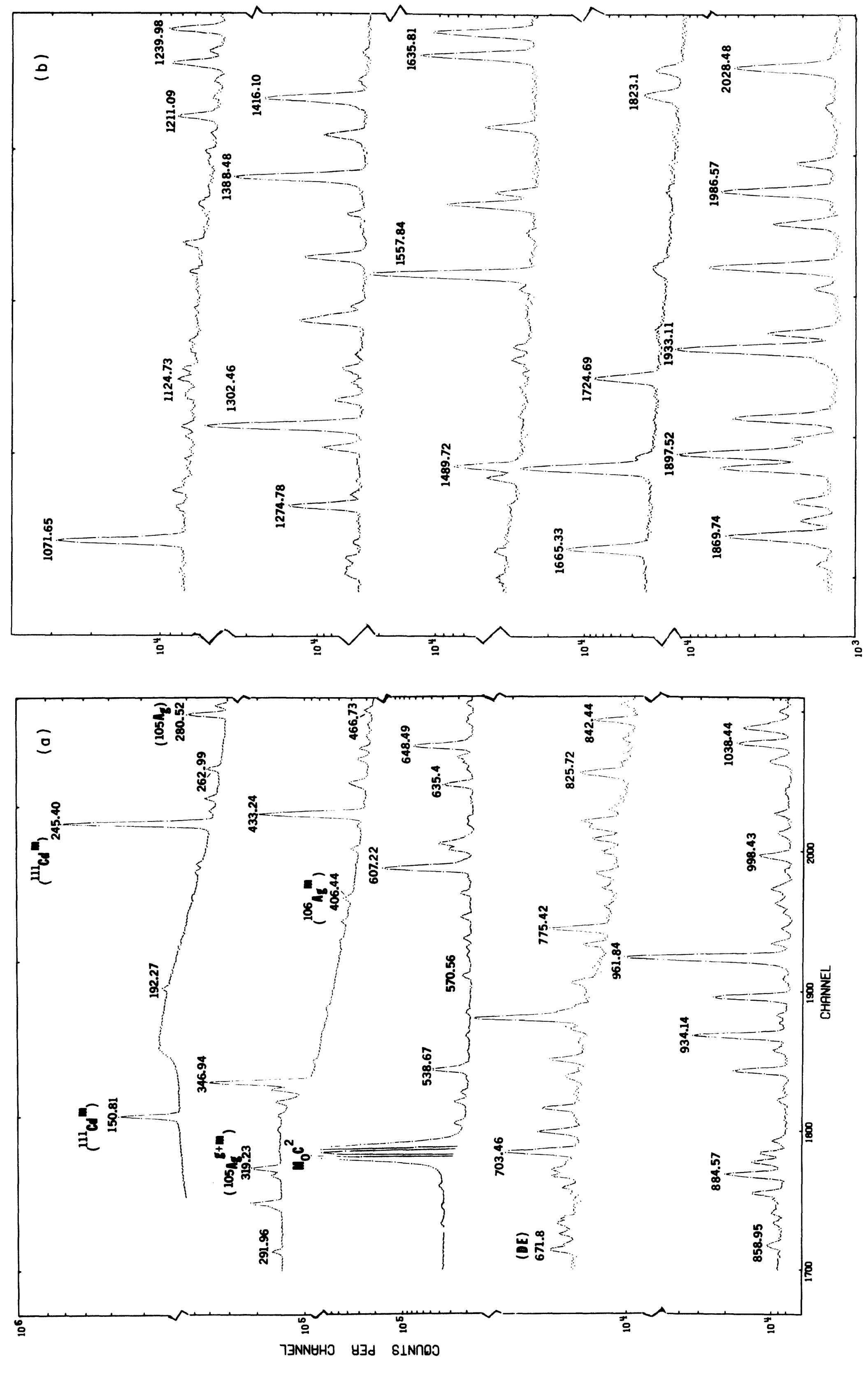


FIG. 1. γ-ray spectrum of ^{105}Cd observed with the 50 cm^3 Ge(Li) detector between (a) 100 and 1050 keV, (b) 1050 and 2050 keV.

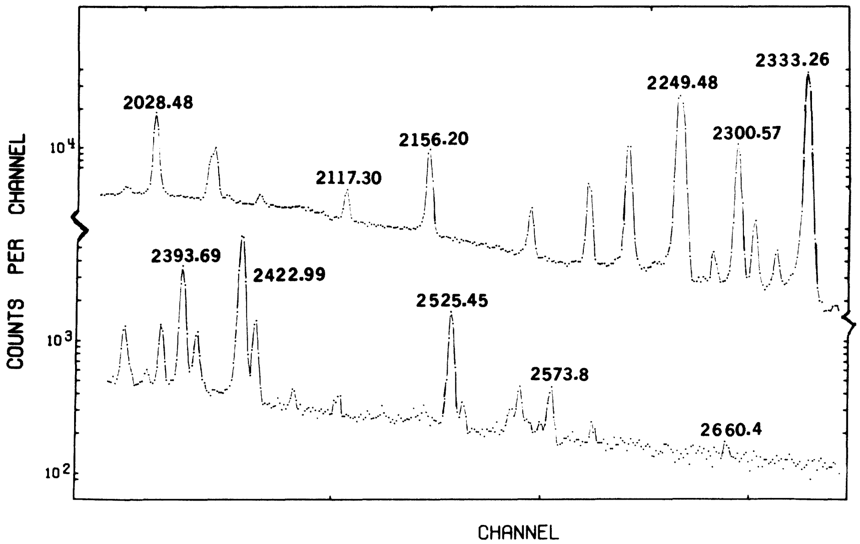


FIG. 2. γ-ray spectrum of ^{105}Cd between 1950 and 2760 keV observed with the 80 cm^3 Ge(Li) detector through a 2.54 cm Pb absorber.

diation ($t=0$) was determined by extrapolation of the decay curve. The amount of ^{105}Ag was determined ~32 days later by counting the sample at a known geometry and using the ^{105}Ag decay scheme of Kawakami and Hisatake.[42] Then the β^+/EC branch was determined by using the data in Table I as well as the equations of radioactive growth and decay.

A balance of the intensities of the γ rays placed into and out of the 53.2-keV level of ^{105}Ag assuming no direct β decay resulted in a value for the total conversion coefficient (α_{total}) of the 27.7-keV γ transition of $(49\pm6) \leq \alpha_{\text{total}} \leq (56\pm6)$. The two values resulted from the double placements of the 2274.83- and 2393.69-keV γ rays. A comparison with the theoretical α_{total} of a 27.7-keV transition indicates that this transition is $M1+(25\pm4)\%$ $E2$.

A majority of the excited states of ^{105}Ag have been assigned on the basis of precise energy sums and differences and on the basis of our coincidence measurements (see Table I and Fig. 3). A large number of these levels were also observed in the (^{3}He, d) reaction study[26] and/or in the (p, t) reaction study.[25] Only three levels, 1885.6 keV, 2494.8 keV, and 2584.1 keV, are placed solely on energy sums; and, of these, a marginal 1360.79- by 499.45-keV coincidence supports the first, and a 2583-keV level observed in the (p, t) reaction supports the third.

C. γ-γ coincidence spectroscopy

The γ-γ coincidence measurements were carried out at LLL using two large-volume true-coaxial Ge(Li) detectors (both ~50–60 cm^3, having effective FWHM energy resolutions in the two-parameter system of 3.0 and 3.3 keV at 1332 keV) in conjunction with a multiparameter pulse-height-analyzer system and associated electronics described elsewhere.[44] The coincidence time gate was approximately 35 nsec, resulting in a real-to-random coincidence ratio of about 15 to 1. The coincidence events were recorded on magnetic tape in an 8192 by 8192 channel format for later analysis using the LLL CDC7600 computer system along with computer codes developed at LLL.[45] Approximately 2.3 million coincidence events were recorded on magnetic tape. During analysis, coincidence spectra were extracted for 39 peak regions as well as for neighboring regions to account for Compton backgrounds. Energy gates were set on the spectrum obtained with the "stop" detector (FWHM) = 3.3 keV). The results obtained are in Table I. Marginal coincidences, indicated in parentheses, were doubtful peaks in the coincidence spectra that agreed in energy with transitions seen in γ-ray singles spectra. These transitions could be placed between established levels on the basis of energy sums such that the placement was consistent with the observation of a coincidence.

III. ^{105}Cd DECAY SCHEME

In Fig. 3 we present the decay scheme of ^{105}Cd to levels of ^{105}Ag. These levels and their properties as determined in this study as well as in the ^{104}Pd(^{3}He, d)^{105}Ag reaction study[26] and in the ^{107}Ag(p, t)^{105}Ag reaction study are shown in Table II. The properties of ten additional levels not shown in Fig. 3 are also listed. Energies and relative intensities of the γ rays are presented vertically above the γ-ray transition line with the relative intensity value in parentheses. Intensi-

TABLE I. γ rays observed in the decay of 55.5-min ^{105}Cd.

Energy [a] (keV)	Intensity [a,b]	Notes [c]	Transition [d] (from/to)	Coincident [e] γ rays in ^{105}Cd decay or identification [f]
27.7 (6)	45 (5)		53/25	
51.7 (2)	4 (2)	Q	2308/2256	
86.33 (7)	21 (2)		433/346	
107.6 (3)	1.2 (7)	Q		Not placed
128.6 (2)	1.6 (6)		(1923/1794	
132.9 (2)	4 (2)		1690/1557	
171.34(16)	12 (4)		1557/1386	
172.82(13)	16 (3)		1923/1750	(1403)
192.27 (9)	19 (2)		1750/1557	1557
221.76(12)	7 (1)			Not placed
229.82 (9)	15 (2)		1557/1327	1302
232.37 (8)	18 (2)		1923/1690	1665
249.41 (6)	14 (2)	T	Multiplet	1360, 1388
	5 (3)	C	1690/1441	
	10 (4)	C	1635/1386	
253.42 (3)	31 (2)		1923/1669	283, 1644
262.99 (3)	39 (2)		1557/1294	307, 346, (775), 948, 1294
283.29 (4)	33 (2)		1669/1386	253, 316, 1360
291.96 (4)	47 (2)		1586/1294	307, 346, 662, 746, (842), 948, 1294
295.7 (3)	3 (2)		1986/1690	
306.35 (5)	29 (15)	105		^{105}Ag^{m} decay [21]
307.83 (3)	192 (7)	T	Multiplet	262, 291, 340, 613, (640), (697), 934, 961, 1038, 1274, 1302
	12 (5)	C	1294/987	
	180 (12)	MC	1635/1327	
316.82 (5)	53 (2)		1986/1699	283, (1322), 1644
319.23 (3)	189 (4)	105		^{105}Ag^{m} decay [100]
325.0 (2)	5 (2)			Not placed
340.66 (4)	97 (3)	T	Multiplet	304, 934, 948, 961, (1294)
	14 (6)	C	1635/1294	
	83 (9)	MC	1327/987	
343.4 (2)	≤6	SL, 105	(1586/1243)	
346.87 (2)	896 (9)		346/g.s.	262, 292, 530, 640, 695, 746, 896, 948, (1006), 1038, (1039), 1211, 1239, 1322, 1343, 1403, 1902, 1909, (1953), 1960, 1986, 2053, (2076), 2203
353.91(12)	9 (2)			Not placed
362.9 (3)	4 (2)		(1386/1023) or (1690/1327) or (2081/1718)	
371.28(10)	9 (2)			Not placed
398.99 (8)	12 (1)		1386/987	961
403.3 (4)	3 (2)		2326/1923	
417.1 (2)	3 (2)		1294/877	
422.27 (6)	19 (1)		1750/1327	1302
433.24 (3)	600 (5)		433/g.s.	590, 609, (613), 733, 810, 1124, (1159), 1360, 1489, (1552), 1823, (1867), (1874), 1881, 1892, (1894), 1900, 1938, 1995, 2117
442.3 (2)	18 (3)	105		^{105}Ag^{m} decay [9.4]
443.9 (2)	≤4	SL, L, 105	(1885/1441)	
444.6 (2)	≤4	SL, L, 105	(877/433)	
454.38 (7)	23 (2)		(1441/987)	934, 961
458.3 (11)	11 (2)			Not placed
461.96(11)	10 (2)		2256/1794	
466.73 (7)	11 (2)		1794/1327	1302
486.73(10)	14 (2)	105	(2473/1986) or (2156/1669)	

TABLE I *(Continued)*

Energy [a] (keV)	Intensity [a,b]	Notes [c]	Transition [d] (from/to)	Coincident [e] γ rays in ^{105}Cd decay or identification [f]
499.45 (8)	14 (2)	T	(Multiplet)	(1360)
	8 (4)	C	1885/1386	
	6 (6)	MC	(2249/1750)	
520.54 (5)	24 (1)		2314/1794	
530.95 (8)	16 (1)		877/346	346
538.67 (6)	151 (5)		1635/1097	(613), 1043, 1071
545.0 (2)	3 (1)		1986/1441	
550.17(11)	8 (1)		(2300/1750) or (2473/1923)	
558.14(10)	8 (1)		2308/1750 or (1885/1327)	(1403), (1724)
560.9 (3)	2 (1)			^{105}Ag^{m} decay [0.5]
570.56 (6)	23 (2)		1557/987	(934), 961
576.1 (5)	3 (2)	Q	2326/1750	
577.4 (2)	9 (2)		2371/1794	
579.97 (9)	12 (1)		2249/1669	1644
583.17 (6)	18 (1)		2333/1750	1403, (1724)
590.44 (5)	25 (1)		1023/433	433, 1302
598.54 (5)	25 (2)		2156/1557	1557
607.22 (2)	798 (7)		2326/1718	1665/1693
609.45 (5)	23 (2)		1042/433	433, 613
613.5 (4)	73 (2)	T	Multiplet	307, (433), 538, 609, (648), 1043, (1665)
	21 (13)	C	2249/1635	
	52 (15)	MC	1656/1042	
617.41 (9)	16 (6)	105, 105*m*	2308/1690	(703), (1665)
623.7 (2)	14 (1)		2314/1690	1665
630.8 (3)	8 (3)		2300/1669	
635.4 (3)	102 (2)		2326/1690	703, 1343, 1665
640.46 (8)	13 (2)		987/346	(307), 346, (648)
642.8 (6)	20 (2)		2333/1690	1665
648.49 (2)	335 (5)	105*m*	1635/987	(613), (640), (697), 934, 961
656.53 (7)	15 (1)	105*m*	2326/1669	1644
658.27 (8)	13 (1)	T	Multiplet	(1302)
	7 (6)	C	1986/1327	
	6 (7)	MC	(2328/1669)	
662.79 (7)	17 (2)		2249/1586	292
676.88(12)	10 (1)		1023/346	
681.97(16)	7 (2)	105, 106	1669/987	(961)
691.88(13)	9 (2)		(2249/1557) or (2328/1635)	
695.76(10)	16 (2)		1042/346	346
697.7 (2)	19 (1)		2333/1635	(307), (648), (1635)
700.07(16)	9 (1)		2419/1718	1693
703.46 (8)	64 (2)	106*m*	1690/987	(617), 635, 934, 961
709.87 (8)	27 (2)		2400/1690	1665
714.8 (6)	4 (3)	Q	2156/1441	
721.6 (4)	4 (2)	Q	2308/1556	
727.54(13)	12 (2)		2314/1586	
733.03 (9)	24 (2)		1166/433	433, (1159), (1256)
738.8 (3)	4 (2)		2326/1586	
746.44 (7)	114 (2)		2333/1586	292, 346
749.7 (3)	8 (2)		2419/1669	
755.9 (3)	6 (2)		2550/1794	
758.07(15)	18 (2)		1635/877	877
762.8 (3)	4 (2)		1750/987	
770.18(12)	12 (2)		2156/1386	(1360)
775.41 (7)	41 (2)		2333/1557	(262), 1557
782.4 (3)	4 (2)	105*m*	2473/1690	

TABLE I *(Continued)*

Energy [a] (keV)	Intensity [a,b]		Notes [c]	Transition [d] (from/to)	Coincident [e] γ rays in ^{105}Cd decay or identification [f]
788.7 (2)	6	(2)		1885/1097	
800.23(16)	10	(2)		2550/1750	
810.1 (8)	26	(1)		1243/433	433
813.9 (2)	8	(2)		(2400/1586) or (2371/1557)	
825.72(15)	26	(3)	106*m*	1923/1097	1044, 1071
827.7 (6)	2	(2)	Q	2156/1327	
836.3 (3)	5	(2)		2422/1586	
842.44 (8)	23	(1)	T	Multiplet	(292), 1557
	14	(4)	C	2400/1557	
	7	(5)	MC	2429/1586	
858.95(12)	21	(2)	T	2300/1441	1388
	≤5		L	2494/1635	
866.9 (2)	10	(1)		2308/1441	(1388), (1416)
870.88(14)	10	(3)		2429/1557	1557
877.81 (9)	46	(2)		877/g.s.	758
884.57 (8)	126	(2)		2326/1441	(454), 1388, 1416
889.13 (8)	54	(2)		1986/1097	1044, 1071
892.21 (8)	38	(2)	T	2308/1416	1416
	≤6		L	2333/1441	
896.61 (9)	18	(2)		1243/346	346
921.62 (5)	102	(2)		2249/1327	340, 1274, 1302
928.8 (2)	7	(4)	105*m*	2256/1327	
934.14 (4)	271	(3)		987/53	307, 340, 454, (570), 648, 703, (998), (1169), 1338, 1340, 1413, 1485
941.6 (11)	13	(2)		2328/1386	1360
948.04 (4)	182	(3)		1294/346	262, 291, 340, 346, (746), 1013, (1031), 1038
954.53(12)	6	(2)		2249/1294	
961.84 (3)	1000	(7)		987/25	307, 340, 398, 454, 570, (635), 648, (681), 703, 998, 1169, 1262, 1327, 1388, 1340, 1413, 1485
967.23 (6)	26	(2)			Not placed
972.48(10)	12	(2)		2300/1327	(1302)
978.22(15)	12	(2)		2419/1441	
981.5 (9)	29	(3)		2422/1441	(1388), 1416
984.58(17)	15	(4)		2081/1097	1071
986.91(10)	35	(3)		2314/1327	1302
992.93(14)	9	(2)		2550/1557	(1557)
998.43 (5)	63	(3)	T	Multiplet	(934), 961, 1302
	20	(6)	C	1986/987	
	31	(8)	C	2325/1327	
	12	(17)	MC	(1023/25)	
1006.25 (9)	16	(3)		2249/1243	(346)
1013.51 (8)	22	(2)		2308/1294	948
1021.5 (2)	7	(3)			Not placed
1031.86(13)	30	(4)	T	Multiplet	(948), 1388, 1416
	10	(7)	C	2326/1294	
	15	(10)	C	2473/1441	
1033.1 (2)	15	(4)		2419/1386	(1360)
1038.44 (6)	125	(2)		2333/1294	307, 346, 948, 1294
1039.4 (2)	≤6		L	1386/346	(346)
1043.46 (7)	105	(3)	T	Multiplet	538, 613, 825, 889, 1228
(1042.7 (1))	45	(17)	MC	1042/g.s.	
(1044.0 (1))	60	(14)	C	1097/52	
1061.4 (3)	4	(2)		2447/1386	
1071.65 (5)	273	(4)		1097/25	538, 825, 889, 984, 1228, 1322, 1375
1082.56(16)	13	(3)		2326/1243	
1091.0 (3)	6	(2)		2419/1327	

TABLE I (*Continued*)

Energy [a] (keV)	Intensity [a,b]	Notes [c]	Transition [d] (from/to)	Coincident [e] γ rays in ^{105}Cd decay or identification [f]
1095.7 (4)	3 (2)		2422/1327	
1098.5 (3)	3 (2)			^{105}Ag^m decay [3.7]
1105.8 (2)	6 (1)		2400/1294	
1109.15(13)	10 (1)	T	(Multiplet)	
	8 (4)	C	2550/1441	(1388), (1416)
	≤6	L	(2494/1386)	
1119.7 (2)	13 (2)		2447/1327	1302
1124.73 (8)	20 (2)		1557/433	433
1137.2 (2)	8 (2)			Not placed
1144.7 (3)	3 (1)		2473/1327	
1147.9 (4)	2 (1)		2314/1166	
1159.75(16)	14 (3)	T		Not placed
	≤7	L	(2256/1097)	
1169.09 (8)	24 (2)		2156/987	(934), 961
1196.3 (3)	5 (1)			Not placed
1205.4 (3)	4 (2)		2371/1166	
1211.09 (7)	42 (3)		1557/346	346
1217.5 (2)	4 (1)		(2314/1097) or (1243/25)	
1228.74 (6)	52 (4)		2326/1097	1044, 1071
1232.84(13)	14 (2)		2256/1023	
1239.98 (5)	61 (2)		1586/346	346
1256.5 (10)	23 (2)	T		Not placed
	≤6	L	(2584/1327)	
1262.24(14)	8 (2)		2249/987	961
1274.78 (4)	175 (3)		1327/52	307
1283.6 (3)	5 (2)		2326/1042	
1289.6 (4)	6 (2)		2584/1294	
1294.89 (4)	66 (2)		1294/g.s.	262, 291, (340), 1038
1302.46 (2)	868 (6)	T	Multiplet	229, 307, 422, 466, 590, (658), 921 (972), 986, 998, 1119
	20 (10)	C	2326/1023	
1416.1 (10)	350 (10)	T	Multiplet	(866), 884, 892, 981, 1031, (1109)
	40 (15)	C	1416/g.s.	
	310 (25)	MC	1441/25	
1422.19(15)	6 (2)	E	2300/877	
1431.85(16)	9 (2)		2419/987	
1459.62(13)	18 (3)		2447/987	961
1465.1 (4)	3 (2)			Not placed
1469.1 (6)	2 (2)	Q		Not placed
1485.71 (8)	36 (2)		2472/987	(934), 961
1489.72 (5)	95 (2)		1923/433	433
1507.8 (3)	5 (1)		(2550/1042) or (2494/987)	
1522.9 (3)	4 (2)		2400/877	
1532.32(12)	14 (2)		1557/25	
1552.8 (3)	7 (2)		1986/433	(433)
1557.84 (4)	437 (4)		1557/g.s.	192, 598, 775, 842, 866, (992)
1582.56 (7)	135 (2)		1635/52	
1586.84 (8)	44 (2)		1586/g.s.	
1610.3 (6)	56 (3)		1635/25	
1635.81 (6)	223 (4)		1635/g.s.	(613), (697)
1644.03 (7)	186 (3)		1669/25	253, 316, 579, 656
1665.33 (6)	278 (4)	T	Multiplet	232, 607, (617), 623, 635, 642, 709
(1665.2 (8))	75 (14)	C	1718/52	
(1665.65(10))	203 (18)	MC	1690/25	
1693.34 (5)	755 (5)		1718/25	607, 700
1697.2 (2)	25 (3)		1750/53	
1724.69 (7)	148 (3)		1750/25	(558), (583)

TABLE I *(Continued)*

Energy [a] (keV)	Intensity [a,b]	Notes [c]	Transition [d] (from/to)	Coincident [e] γ rays in ^{105}Cd decay or identification [f]
1741.8 (4)	7 (2)		1794/53	
1797.5 (4)	5 (2)		2144/346	
1809.0 (4)	5 (1)		2156/346	
1823.1 (2)	33 (7)		2256/433	433
1831.67(14)	33 (2)		(1884)/25	
1853.6 (8)	1 (1)	Q		Not placed
1860.1 (2)	8 (2)		1885/25	
1867.3 (3)	10 (2)		2300/433	(433)
1869.74 (9)	136 (3)		1923/53	
1874.99(14)	19 (2)		2308/433	(433)
1881.36(12)	28 (2)		2314/433	433
1892.89 (8)	151 (2)		2326/433	433
1894.8 (3)	10 (8)	C	2328/433	(433)
1897.52 (7)	308 (3)		1923/25	
1900.21(13)	25 (2)		2333/433	433
1902.79(13)	28 (2)		2249/346	346
1909.69 (8)	130 (3)		2256/346	346
1929.1 (2)	10 (2)		2276/346	
1933.11 (8)	339 (3)		1986/52	
1938.5 (9)	63 (2)		2371/433	433
1953.51(16)	13 (1)		2300/346	(346)
1960.89 (9)	200 (3)	T	Multiplet	346
	11 (7)	C	2308/346	
	189 (10)	MC	1986/25	
1975.66(10)	52 (7)	A		Not placed
1986.57 (7)	161 (2)		2333/346	346
1995.97(10)	29 (3)		2429/433	433
2014.0 (3)	7 (2)	E	2447/433	
2028.48 (7)	135 (4)		2081/53	
2053.6 (14)	34 (2)		2400/346	346
2056.06(13)	52 (2)		2081/25	
2061.5 (3)	5 (1)		2494/433	
2076.5 (4)	8 (1)		2422/346	(346)
2095.2 (6)	2 (1)	Q		
2117.3 (15)	19 (2)		2550/433	433
2156.2 (11)	80 (3)		2156/g.s.	
2203.58(14)	21 (1)	T	(Multiplet)	346
	20 (8)	C	2550/346	
	≤8	MC	(2256/52)	
2230.88(12)	42 (2)		2256/25	
2249.48(10)	105 (4)		2249/g.s.	
2272.85(15)	220 (12)		2326/52	
2274.83(15)	180 (12)		(2300/25) or (2328/52)	
2288.9 (2)	6.4 (7)		2314/25	
2300.57 (9)	110 (4)		(2300/g.s.) or (2326/25)	
2308.3 (12)	22 (1)		2308/g.s.	
2318.5 (14)	10.4 (9)		2371/53	
2333.26 (5)	422 (14)		2333/g.s.	
2345.7 (7)	0.8 (5)	Q	2371/25	
2364.6 (13)	10.5 (6)	A		Not placed
2375.2 (3)	1.6 (5)		2400/25	
2382.66(12)	10.2 (6)	A		Not placed
2393.69 (9)	38 (1)		(2447/53) or (2419/25)	
2400.37(15)	9.4 (7)		2400/g.s.	
2422.99(10)	75 (3)		2422/g.s.	
2429.19(14)	13 (6)		2429/g.s.	

TABLE I *(Continued)*

Energy [a] (keV)	Intensity [a,b]	Notes [c]	Transition [d] (from/to)	Coincident [e] γ rays in ^{105}Cd decay or identification [f]
2447.5 (3)	≤0.1	106	(2473/25)	
2469.5 (5)	1.3 (3)		2494/25	
2512.1 (5)	0.7 (3)	A		Not placed
2525.45(18)	16.7 (7)		2550/25	
2530.8 (3)	1.3 (3)		2584/53	
2554.3 (4)	1.2 (3)	A		Not placed
2558.8 (2)	3.2 (3)		2584/25	
2568.5 (8)	0.5 (3)	A		Not placed
2573.8 (2)	3.2 (3)	A		Not placed
2594.5 (5)	0.7 (2)	A		Not placed
2660.4 (6)	0.4 (2)	A		Not placed

[a] Value shown as 27.70(6), for example, means 27.70± 0.06. The uncertainties are one standard deviation.

[b] The intensity values are relative to a value of 1000 for the 961.84-keV transition. To convert to absolute intensity (per 1000 decays), multiply the relative intensity value by 0.0469± 0.0029. This includes the absolute branch to the $\frac{7}{2}^+$ 25.5-keV state of 51.4%. An uncertainty of 2% must be added in quadrature to reflect the uncertainty in the Ge(Li) detector efficiency.

[c] The notes to the table mean the following: Q: The presence of this transition is in some doubt. Generally this is a weak peak with large uncertainty and may not have been observed in all singles spectra. T: The transition intensity is that observed for the single peak in singles spectra. C: The transition intensity was obtained from coincidence measurements. MC: The transition intensity is the result of subtracting the intensities noted "C" from the total intensity (noted "T"). 105, etc.: The transition intensity has been corrected for contributions from the decay of this Ag isotope. SL: The intensity limit is from singles spectra. L: The intensity limit is from coincidence measurements. E: The intensity has been corrected for the presence of an escape peak. A: This γ ray determines a level at (E), $(E+25.5)$, or $(E+53.2)$ keV. It is either not coincident with the 346- or 433-keV γ rays, or Q_{EC} considerations preclude its placement into any level but ground state, 25.5, or 53.2 keV.

[d] Assignments are made on the basis of energy sums and coincidence relationships. Multiple assignments and assignments of transitions with intensity limits are in parentheses and are dotted in the level scheme. These assignments are consistent with being dipole or electric quadrupole in character and the energy sums involved give no preference for placement.

[e] Coincidences in parentheses are marginal. These are indicated in the level scheme by the use of open circles to indicate the coincidence.

[f] The assignments to the decay of 7.23-min ^{105}Ag^m are based on the work of Krien *et al.* (Ref. 41). The values in parentheses are the relative intensity values from that work. Transitions not placed are thought to come from ^{105}Cd decay on the basis of half-lives and/or consistent values for relative intensity.

ties given as (896 + 15), for example, indicate γ-ray intensity plus theoretical conversion electron intensity,[46] respectively. An exception is the 27.70-keV transition for which the conversion electron intensity was determined from transition intensity balance. In the γ-γ coincidence experiment energy gates were set on those γ rays depicted in Fig. 3 with a dot on their upper end, whereas those γ rays observed in the resulting coincidence spectra are indicated by a filled dot at their lower end. Marginal coincidences are indicated by open circles at the lower end of the transition. Dashed transitions signify either transitions for which the relative intensity value is an upper limit or transitions that are also placed elsewhere in the level scheme with no evidence to support one placement over the other.

In making intensity balances to determine direct β^+/EC decay feeding to the levels of ^{105}Ag, we assumed that there was no direct β^+/EC decay from $\frac{5}{2}^+$ ^{105}Cd to the ground state ($\frac{1}{2}^-$) or to the 53.2-keV excited state ($\frac{9}{2}^+$). The Q_{EC} value of Wapstra and Gove[47] for ^{105}Cd of 2800 ± 100 keV and the $\log(f_0^\epsilon + f_0^+)$ tables of Gove and Martin[48] were used to calculate log*ft* values. As noted in Table II, when two log*ft* values are given for a level, one value arises from performing the intensity balance for the level without including any dashed transitions, and the other arises from including them.

The second excited state of ^{105}Ag was observed in the (^{3}He, *d*) and (*p*, *t*) reaction and is placed at 53.2 keV on the basis of a 27.70-keV transition (to the 25.5-keV level) as well as the observation of numerous 27.7-keV differences between strong γ rays. The levels at 346.87, 433.24, and 877.81 keV were observed in the (^{3}He, *d*) and (*p*, *t*) reaction, and their energies are based on observed γ transitions to the ground state. In addition, the placement of the level at 877.81 keV is substantiated by a 346.87- by 530.95-keV coincidence.

TABLE II. ^{105}Ag levels observed in the β^+/EC decay of 55.5-min $\frac{5}{2}^+$ ^{105}Cd.

Energy (keV)	Absolute β^+ + EC branch [a]	σ [b]	logft	Note	J^π assignment	(^{3}He, d) [c] l value	C^2S_{lj}	(p, t) [d] l value	$\sigma(20°)$ (μb/sr)
0	0	···	···	e	$\frac{1}{2}^-$	1	0.46	0	561
25.5	51.4	4.0	5.4		$\frac{7}{2}^+$				
53.2	0	···	···	e	$\frac{9}{2}^+$	4	1.57		3
346.87	≤0.06	···	≤8.1	f	$\frac{3}{2}^-$	1	0.21	2	30
433.24	0	···	≤10.1	f	$\frac{5}{2}^-$	(3)?		2	43
877.81	0.15	0.03	7.3		$\frac{3}{2}^-$	1	0.19	2	5.6
987.3	1.67	0.14	6.2		$\frac{5}{2}^+$	2	0.52		
1023.68	0.042	0.094	(7.8)	g	$\frac{7}{2}^-$			4	6.9
1042.68	0.13	0.13	(7.3)	g	$\frac{5}{2}^-$	Seen		2	9.0
1097.1	≤0.02	···	≤8.0	f	$\frac{9}{2}^+$	Seen			0.4
1166.7	0	···	≤9.6	f	$\frac{9}{2}^-$	Seen		4	10
1243.41	0.070	0.042	7.4		$\frac{5}{2}^-$				
1294.89	≤0.01	···	≤8.1	f	$\frac{1}{2}^+$	0	0.17		
1327.9	3.05	0.23	5.7		$\frac{5}{2}^+$	2	0.86		
1386.3	0.16	0.09	6.9		$\frac{3}{2}^+, \frac{5}{2}^+$	2	0.08, 0.06		
1416.1	0.009	0.009	(8.2)	g	$(\frac{1}{2}^-, \frac{3}{2}^-, \frac{5}{2}^-)$				
1441.7	3.17	0.24	5.6		$\frac{5}{2}^+$	2	0.03		1.7
1543.2	0.02	0.005	7.7		$\frac{3}{2}^-, \frac{5}{2}^-$			2	24
1557.84	2.25	0.16	5.7		$\frac{3}{2}^+$	2	0.12		
1586.84	≤0.005	···	≤8.4	f	$\frac{1}{2}^+$	0	0.04		
1635.8	5.08	0.33	5.3	h	$\frac{3}{2}^+$ and $\frac{5}{2}^+$	2	0.16, 0.12		
	≥0.91		≤6.0	i	$\frac{3}{2}^+$				
	≥1.15		≤5.9	i	$\frac{5}{2}^+$				
1656.2	0.24	0.07	6.6		$(\frac{7}{2})^-$				
1669.5	0.58	0.07	6.2	j	$\frac{5}{2}^+, (\frac{3}{2}^+)$				0.7
	0.50	0.07	6.3	k	$\frac{5}{2}^+, (\frac{3}{2}^+)$				
1690.7	0.45	0.10	6.3		$\frac{5}{2}^+, (\frac{3}{2}^+)$	Seen			0.7
1718.9	0.089	0.09	(7.0)	g	$\frac{9}{2}^+$				
1750.03	1.11	0.09	5.8		$\frac{5}{2}^+$	2	0.08		
1794.4	0.02	0.05	(7.5)	g	$\frac{7}{2}^+$	4	0.45		
(1884.9)	0.16	0.01	6.6		$(\frac{7}{2}^+)$?	4(2)	1.21		
1885.6	0.12	0.03	6.7		$\frac{5}{2}^+, \frac{7}{2}^+$				
1923.0	2.94	0.19	5.3		$\frac{7}{2}^+$	4	0.67	(6)	1.2
1986.3	3.17	0.21	5.2		$\frac{5}{2}^+$	2	0.05		
2081.7	0.95	0.07	5.6		$\frac{5}{2}^+, \frac{7}{2}^+$	Seen			
2144.4	0.02	0.005	7.2		$\frac{3}{2}^-, \frac{5}{2}^-$			2	18
2156.3	0.74	0.07	5.6		$\frac{3}{2}^+$	Seen			Seen
2249.48	1.53	0.12	5.1		$\frac{3}{2}^+$	Seen		(4)	13
2256.5	1.11	0.09	5.3		$\frac{5}{2}^+$				

TABLE II *(Continued)*

Energy (keV)	Absolute β^+ + EC branch [a]	σ [b]	log*ft*	Note	J^π assignment	(^{3}He, *d*) [c] *l* value	C^2S_{lj}	(*p*, *t*) [d] *l* value	$\sigma(20°)$ (μb/sr)
2276.0	0.05	0.01	6.6		$\frac{5}{2}^+$			3	42
2300.4	1.73	0.12	5.0	j	$\frac{3}{2}^+, (\frac{5}{2}^+)$				
	0.33	0.03	5.7	k	$\frac{3}{2}^+, \frac{5}{2}^+$				
2308.3	0.72	0.07	5.3		$\frac{3}{2}^+$				
2314.6	0.64	0.05	5.4		$\frac{5}{2}^+, (\frac{3}{2}^+)$			3	28
2326.13	8.53	0.53	4.2	j	$\frac{5}{2}^+$	Multiplet			
	8.01	0.50	4.3	k	$\frac{5}{2}^+$				
2328.03	1.33	0.11	5.0	j	$\frac{5}{2}^+, \frac{7}{2}^+$				
	0.42	0.05	5.5	k	$\frac{3}{2}^+, \frac{5}{2}^+, \frac{7}{2}^+$				
2333.26	4.44	0.28	4.5		$\frac{3}{2}^+$			(6)	13
2371.74	0.45	0.04	5.4		$\frac{5}{2}^+, \frac{7}{2}^+$			3	25
2400.37	0.61	0.06	5.2		$\frac{3}{2}^+$				
2419.2	0.52	0.06	5.3	j	$\frac{5}{2}^+, \frac{7}{2}^+$	Seen			
	0.34	0.05	5.4	k	$\frac{5}{2}^+, \frac{7}{2}^+$				
2422.99	0.67	0.05	5.1		$\frac{3}{2}^+$				
2429.19	0.52	0.06	5.3	j	$\frac{3}{2}^+$			(6)	8.7
2447.2	0.39	0.03	5.3	k	$\frac{5}{2}^+, \frac{7}{2}^+$				
	0.22	0.03	5.6		$\frac{5}{2}^+, \frac{7}{2}^+$			2	10
2473.0	0.45	0.06	5.2		$\frac{5}{2}^+, \frac{7}{2}^+$				
2494.8	0.056	0.038	6.0		$\frac{3}{2}^+, \frac{5}{2}^+, \frac{7}{2}^+$				
2550.47	0.45	0.04	4.9		$\frac{3}{2}^+, \frac{5}{2}^+$	(Seen)		2	10
2584.1	0.052	0.014	5.7		$\frac{5}{2}^+$			4	19
~2000	≥0.24	···	≤6.2	l	Probably all $\frac{3}{2}^+, \frac{5}{2}^+, \frac{7}{2}^+$				
~2390	≥0.049	···	≤6.3	l					
~2410	≥0.048	···	≤6.3	l					
~2535	≥0.003	···	≤7.1	l					
~2580	≥0.006	···	≤6.7	l					
~2590	≥0.002	···	≤7.0	l		Multiplet			
~2600	≥0.015	···	≤6.2	l					
~2620	≥0.003	···	≤6.7	l					
~2685	≥0.002	···	≤6.5	l					

[a] This is the number of decays to this level per 100 decays of ^{105}Cd.
[b] All uncertainties are one standard deviation.
[c] The (^{3}He, *d*) data are from the work of Anderson *et al.* (Refs. 14, 26).
[d] The (*p*, *t*) data are from the work of Del Vecchio *et al.* (Ref. 25).
[e] A zero β^+/EC branch to this level was assumed.
[f] The intensity balance results in a negative β^+/EC feeding. The log*ft* limit is the result of adding the uncertainty value to the calculated value. If this resulting feeding were still negative, then the log*ft* limit was obtained by assuming a maximum feeding of 0.1 relative γ-ray units.
[g] The intensity balance results in a positive β^+/EC feeding, but because of the large uncertainty a zero-β branch cannot be ruled out. The log*ft* value is regarded essentially as a lower limit.
[h] This level is thought to be two separate levels. This feeding and log*ft* value represent decay to both levels. The

TABLE II *(Continued)*

log*ft* value, then, is a lower limit for each level.

[i] The log*ft* limits arise from performing the intensity balance using only the transitions that can unambiguously be assigned to the level of the given J^{π}.

[j] This feeding and log*ft* are the limits resulting from performing the intensity balance using all multiply assigned (dotted) transitions.

[k] This feeding and log*ft* are the limits resulting from performing the intensity balance omitting all multiply assigned (dotted) transitions.

[l] These are levels that may be placed at E, $(E+25.5)$, or $(E+53.2)$ keV. The approximate energy value is the γ-ray energy (these are labeled "A" in the γ-ray list) plus ~25 keV.

The level at 987.3 keV was observed in the (^{3}He, d) reaction and is placed on the basis of a 346.87- by 640.46-keV coincidence as well as transitions to the levels at 25.5 and 53.2 keV. The level at 1023.68 keV is placed by a 433.24- by 590.44-keV coincidence and was observed in the (p, t) reaction. The levels at 1042.68, 1097.1, and 1166.27 keV were all populated in the (^{3}He, d) and (p, t) reactions. The first and third of these are placed by coincidences indicating transitions from them to the 433.24-keV level. The 1097.1-keV level is placed on the basis of transitions to the 25.5- and 53.2-keV levels.

The level at 1243.41 keV is placed by 346.87- by 896.61-keV, and 433.24- by 810.10-keV, coincidences. The level at 1294.89 keV was observed in the (^{3}He, d) reaction and is placed on the basis of a γ ray of this energy as well as several coincidences. The levels at 1327.9, 1386.3, and 1441.7 keV were observed in the (^{3}He, d) reaction and are placed by coincidences indicating feeding to the level at 987.3 keV. In addition, the level at 1327.9 keV was observed in the (p, t) reaction. The level at 1416.1 keV was placed on the basis of a strong 1416.10- by 892.21-keV coincidence (=2308.31 keV), indicating a cascade from a level at 2308.30 keV established by other coincidences. The level at 1416.1 keV rather than at 892.2 keV is supported by the failure to observe any coincidences higher in energy than 1416 keV in the 887- to 895-keV coincidence gate, although the background above 1416 keV was virtually nil. The levels at 1557.84 and 1586.84 keV were seen in the (^{3}He, d) reaction study and are placed on the basis of γ rays of these energies as well as numerous coincidences indicating feeding to established lower-lying levels. A level has been placed at 1543.1 keV on the basis of a strong $l=2$ peak in the (p, t) reaction and a 1196.3-keV γ ray that would feed the level at 346.87 keV.

The two levels at 1635.8 keV are placed on the basis of numerous coincidences including 1071.65 and 1044.0 by 538.67 keV, 1302.46 by 307.83 keV, and 877.81 by 758.07 keV. The (^{3}He, d) reaction study indicated an excited state at 1635 ± 4 keV. Our proposal that there are actually two excited states is based on the observation of strong γ transitions to lower-lying levels having spin and parity values of $\frac{9}{2}^+$ and $\frac{1}{2}^-$. (This will be discussed in more detail in the next section dealing with the assignment of spin and parity values.)

The level at 1656.2 keV is established on the basis of 609.45- and 1042.7- by 613.5-keV coincidences, as well as a marginal 695.76- by 613.5-keV coincidence. The level at 1669.5 keV is placed by 1360.79- by 283.29-keV, and 346.87- by 1322.20-keV, coincidences and was observed in the (p, t) reaction. The excited state at 1690.7 keV was seen in the (^{3}He, d) and (p, t) reaction and is placed by 1388.49- by 249.41-keV, and 961.84- by 703.46-keV, coincidences. The level at 1718.9 keV is placed on the basis of transitions to the 25.5-keV and 53.2-keV levels (1693.34 and 1665.65 keV, respectively). These transitions were both observed in the coincidence spectrum from the 604–612-keV coincidence gate.

The levels at 1750.03 and 1794.4 keV were both seen in the (^{3}He, d) reaction and are placed on the basis of coincidences indicating feeding to the level at 1327.9 keV as well as several additional coincidences. The tentative level at 1884.9 keV is placed on the basis of the observation of a high-spin ($l=4$) level at 1880 ± 6 keV in the (^{3}He, d) reaction and the observation of a relatively intense 1831.67-keV γ ray that was not observed in any of the coincidence spectra. The level at 1885.6 keV was placed on the basis of several energy sums involving otherwise unassigned γ rays as well as a marginal 1360.79 by 499.45-keV coincidence. The levels at 1923.0, 1986.3, and 2081.7 keV were all observed in the (^{3}He, d) reaction study and were placed on the basis of coincidences indicating transitions from all three to the 1097.1-keV level as well as several additional coincidences and numerous precise energy sums. The level at 2156.3 keV is placed by 1557.84- by 598.54-keV and 961.84- by 1169.09-keV coincidences and was observed in the (^{3}He, d) and (p, t) reaction studies. A level has been placed at 2144.4 keV on the basis of a strong $l=2$ transition in the (p, t) reaction and

(a)

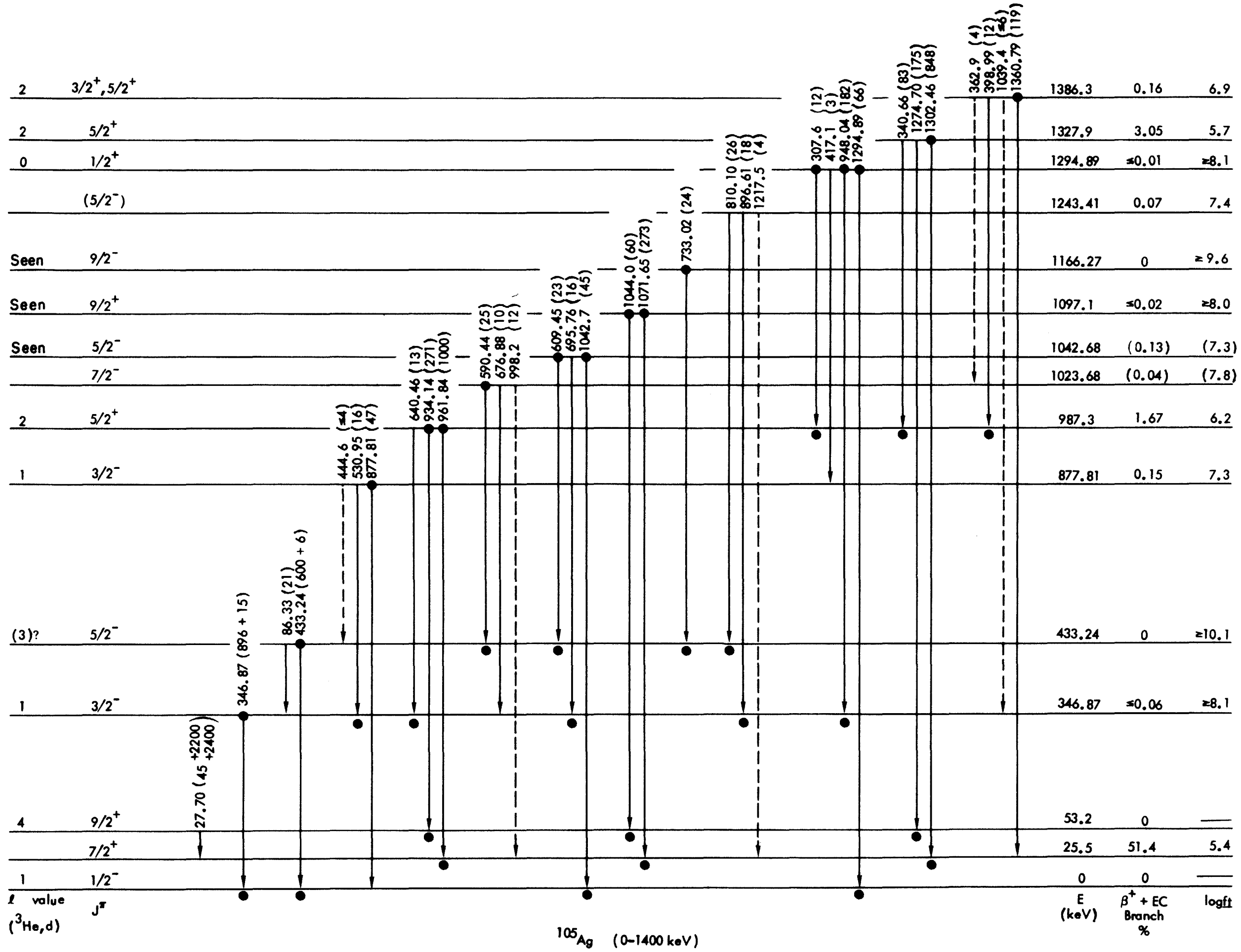
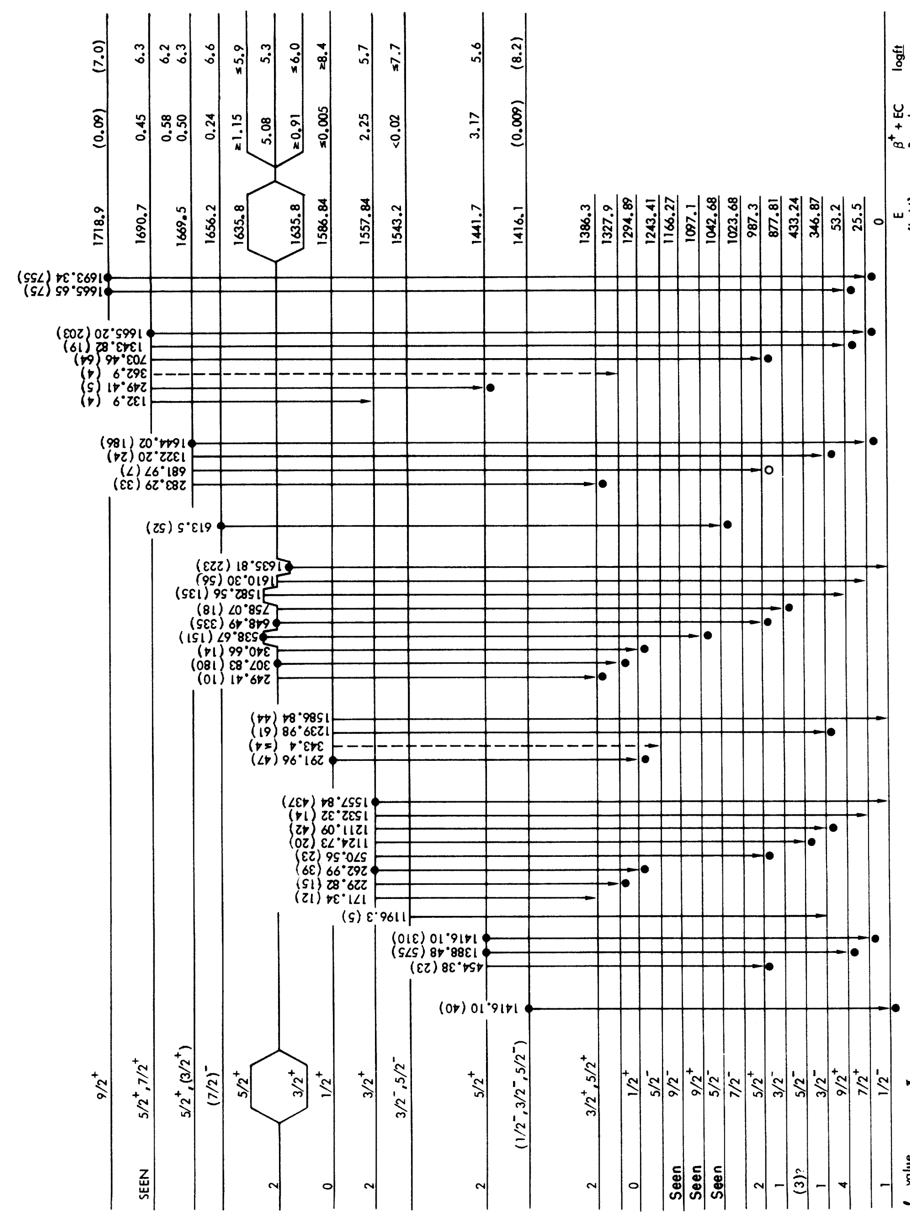


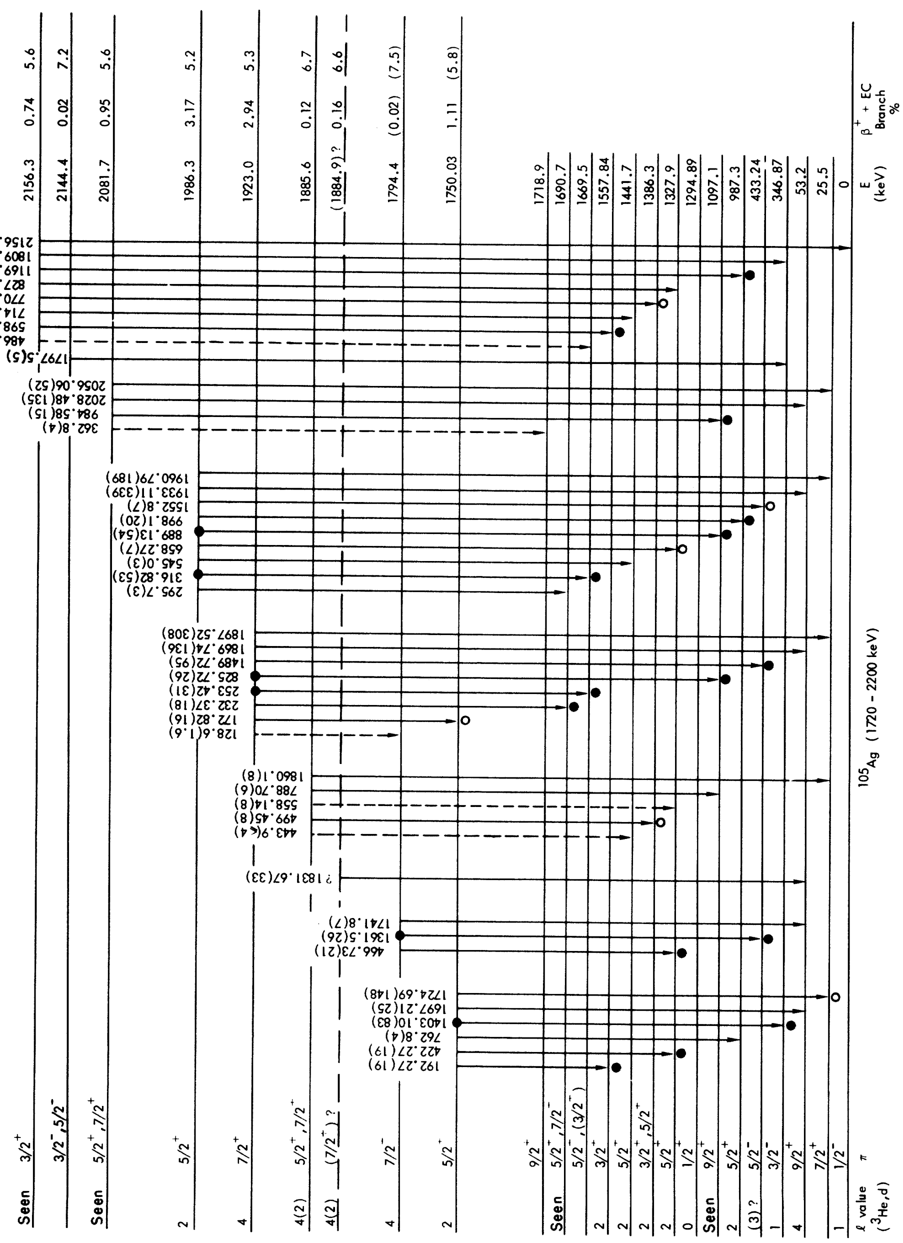
FIG. 3. The decay scheme of 55.5-min ^{105}Cd to levels of ^{105}Ag. The notation is the same as in Table II. Energies and relative intensities of the γ rays are presented vertically above the γ-ray transition line with the relative intensity value in parentheses. Intensities given as (896+15), for example, indicate γ-ray intensity plus theoretical conversion electron intensity, (Ref. 46) respectively (except in the case of the 27.70-keV transition for which the conversion electron intensity was determined from a γ-ray intensity balance). Energy gates were set in the γ-γ coincidence experiment on those γ rays depicted with a dot on their upper end, whereas those γ rays observed in the resulting coincidence spectra are indicated by a filled dot at their lower end. Marginal coincidences are indicated by open circles at the lower end of the transition. Dashed transitions signify either transitions for which the relative intensity value is an upper limit or transitions that are also placed elsewhere in the level scheme with no evidence to support one placement over the other. The partial decay scheme of 55.5-min ^{105}Cd including β^+/EC feedings to the levels of ^{105}Ag between (a) ground and 1400 keV, (b) 1400 and 1720 keV, (c) 1720 and 2200 keV, (d) 2200 and 2320 keV, (e) 2320 and 2410 keV, and (f) 2410 and 2600 keV.



^{105}Ag (1400 - 1720 keV)

(b)

Fig. 3 *(Continued)*



(c)

Fig. 3 *(Continued)*

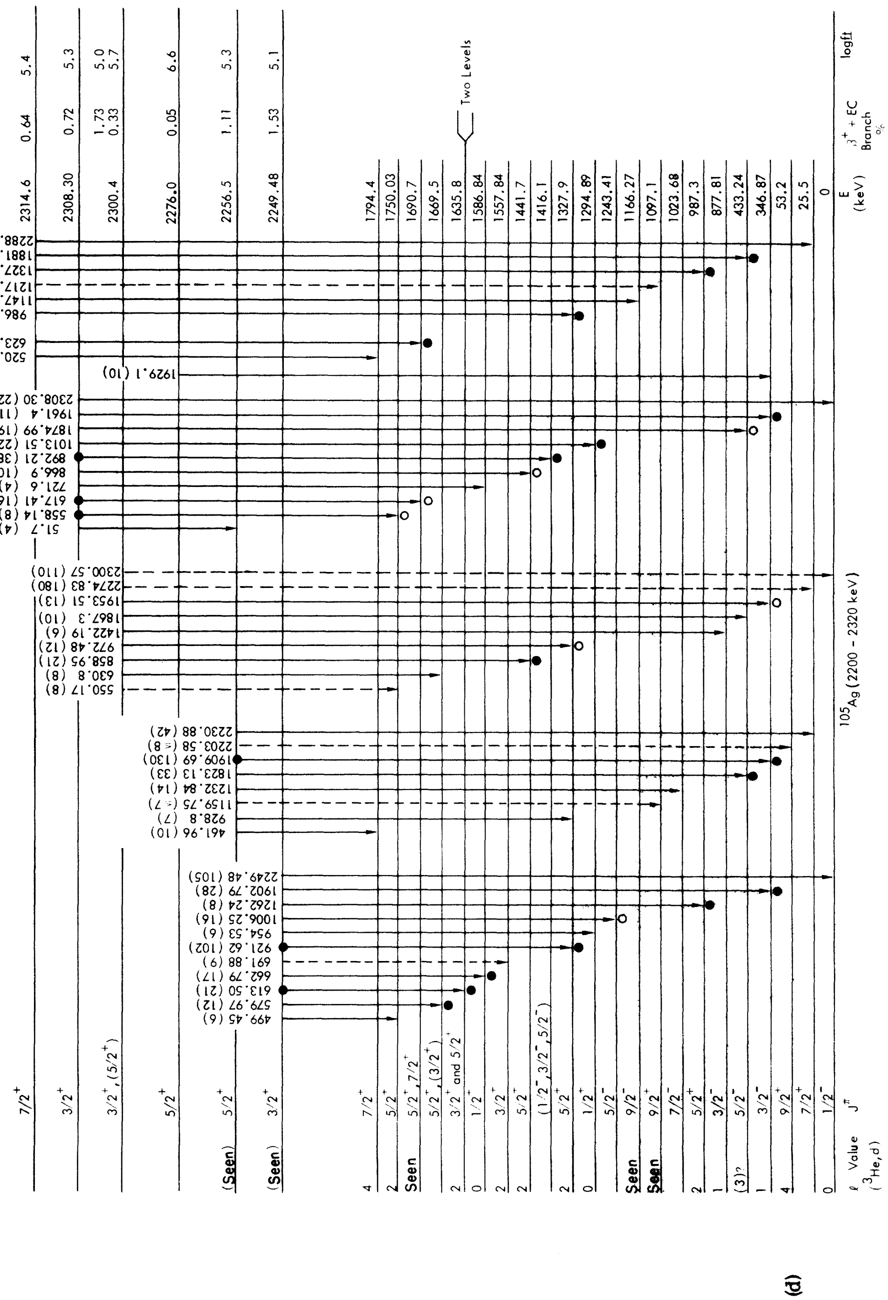
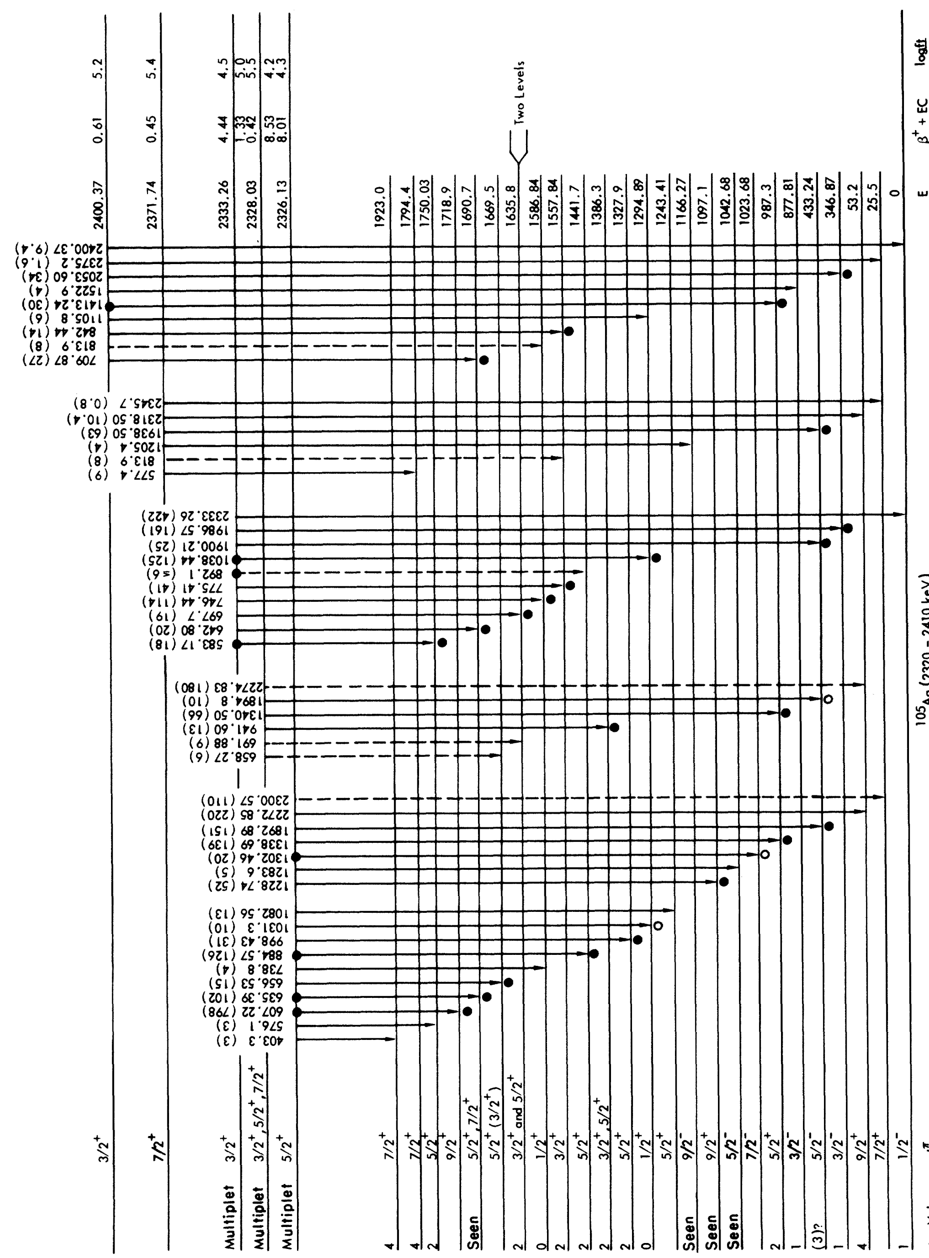
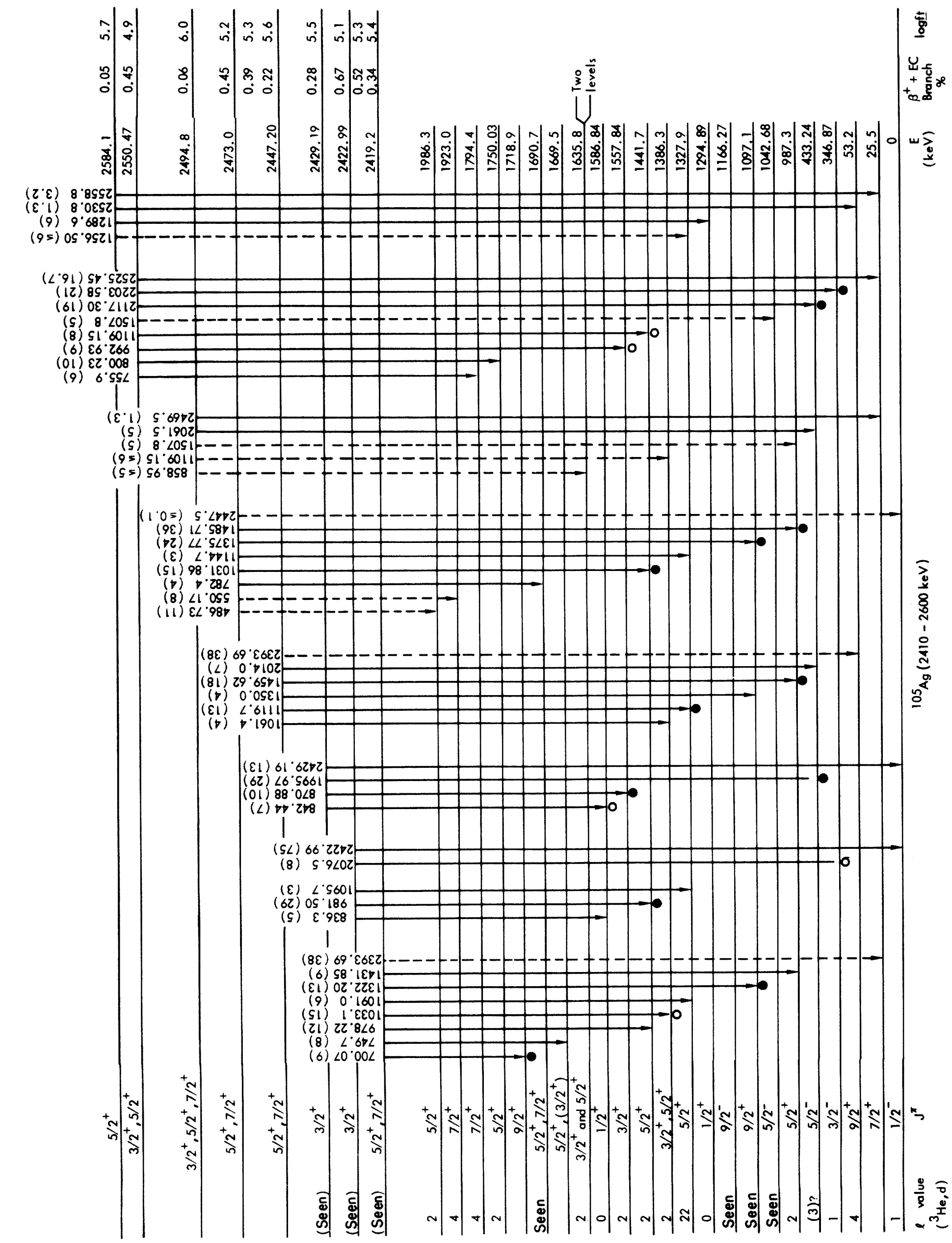


Fig. 3 (Continued)



(e)

Fig. 3 (*Continued*)



(f)

Fig. 3 *(Continued)*

a 1797.5-keV γ ray feeding the 346.87-keV level.

The level at 2249.48 keV is established by numerous coincidences, including 346.87 by 1902.79 keV, 961.84 by 1262.24 keV, and 1644.02 by 579.97 keV. The level at 2256.5 keV is established by coincidences indicating transitions to the levels at 433.24 and 346.87 keV. Levels were seen at 2255 ± 7 keV in the (^3He, d) reaction and at 2252 ± 5 keV on the (p, t) reaction and may correspond to one or the other or both of these two states. The excited state at 2300.4 keV is placed by one good coincidence, 1388.48 by 858.95 keV, as well as by two marginal coincidences and several precise energy sums. The level at 2308.30 keV is placed by several coincidences indicating transitions to the levels at 346.87 keV and 1294.89 keV. The excited state at 2314.6 keV is established by several coincidences, including 433.24 by 1881.36 keV, 961.84 by 1327.20 keV, and 1302.46 by 986.91 keV, and is strongly observed in the (p, t) reaction.[25]

A tentative β branch is placed to the level at 2276 keV observed with a strong $l=3$ transfer in the $^{107}Ag(p,t)^{105}Ag$ reaction by Del Vecchio, Oelrich, and Naumann.[25] The weak 1929.1-keV γ ray will fit to deexcite that level to the $\frac{3}{2}^-$ level at 346.87 keV.

The level at 2326.13 keV is established by eight definite coincidences and two tentative coincidences. The level at 2328.03 keV is established unambiguously by a 1360.79- by 941.60-keV coincidence. The level at 2333.26 keV is placed on the basis of eight coincidences and an intense γ ray of this energy. In the (^3He, d) reaction a multiplet of excited states was observed at 2332 ± 6 keV and a state was observed at 2334 ± 6 keV in the (p, t) reaction. The excited state at 2371.74 keV is placed by a strong 433.24- by 1938.50-keV coincidence and by a strong $l=3$ peak in the (p, t) reaction. The level at 2400.37 keV is placed by several coincidences, including 346.87 by 2053.60 keV and 961.84 by 1413.24 keV.

The level at 2419.2 is placed by 1693.34- by 700.04-keV and 1071.65- by 1322.20-keV coincidences. The level at 2422.99 keV is established by a 1388.48- by 981.50-keV coincidence as well as by two additional marginal coincidences. The level at 2429.19 keV is placed by two good coincidences, 1557.84 by 870.88 keV and 433.24 by 1995.97 keV. Two of these three levels may correspond to the excited state(s) observed at 2420 ± 7 keV in the (^3He, d) reaction and at 2429 ± 5 keV in the (p, t) reaction.

The levels at 2447.20 and 2473.0 keV are placed by coincidences indicating transitions to the 987.3-keV level as well as by additional coincidences and several good energy sums. The excited state at 2550.47 keV is placed by coincidences indicating transitions to the levels at 346.87 and 433.24 keV. The levels at 2494.8 and 2584.1 keV are placed solely on the basis of energy sums involving lower-lying excited states and otherwise unassigned γ rays. The latter may correspond with a 2583-keV level observed in the (p, t) reaction.

Nine additional excited states are listed at the end of Table II, two or three of which may have been observed in the (^3He, d) reaction study. These nine levels involve unassigned γ rays that either cannot be placed into levels above 433 keV because of Q_{EC} and because they are not coincident with either the 346.87- or the 433.24-keV transitions, or cannot be placed into any levels above the 53.5-keV level because of Q_{EC}. These γ rays are noted in Table I by the note "A." The level of energy given in Table II is approximately E_γ plus 25.5 keV; however, any one of three levels of energy is possible, as is noted in a footnote to Table II. No other γ transitions listed in Table I could be placed from these nine levels (27 different possible levels of energy) to any established levels, hence the calculated logft values are given as upper limits.

IV. SPIN AND PARITY ASSIGNMENTS

The spin and parity (J^π) assignments of the levels of ^{105}Cd observed in the β^+/EC decay of 55.5-min $5/2^+$ ^{105}Cd are presented in Fig. 3 and in Table II. These assignments are based on logft values for the β^+/EC decay of ^{105}Cd, the l-transfer values determined in the ^{104}Pd (^3He, d) ^{105}Ag reaction study,[26] the ^{107}Ag (p, t) ^{105}Ag reaction study, the γ-ray deexcitation patterns between levels, and some systematic considerations. The ground states of ^{105}Cd and ^{105}Ag have been measured to be $\frac{5}{2}^+$ and $\frac{1}{2}^-$, respectively.[29] The 25.5-keV isomeric state in ^{105}Ag has been assigned as $\frac{7}{2}^+$ based on L-conversion subshell ratios of the 25.5-keV transition favoring an $E3$ transition.[17,29] The $\frac{7}{2}^+$ assignment is also suggested by analogy with the ^{107}Ag and ^{109}Ag $\frac{7}{2}^+$ $E3$ isomeric states.[9,29]

The 53.2-keV level was observed in the (^3He, d) reaction with an l-transfer value of 4, limiting its spin and parity assignment to $\frac{7}{2}^+$ or $\frac{9}{2}^+$. The large C^2S_{lj} spectroscopic factor obtained, indicative of strong single-particle character, together with general shell-model considerations, favor the $\frac{9}{2}^+$ assignment. The $\frac{9}{2}^+$ assignment is also suggested by analogy with ^{107}Ag and ^{109}Ag, both of which possess a $\frac{9}{2}^+$ excited state lying just above the $\frac{7}{2}^+$ isomeric state in energy.[31,32] The $\frac{9}{2}^+$ assignment is consistent with the lack of any observed transitions from the eight definite $\frac{3}{2}^+$ excited states of ^{105}Ag to the 53.2-keV level.

The excited states at 1294.89 and 1586.84 keV were observed in the (^{3}He, d) reaction, each with an l-transfer value of zero. Hence, they are both assigned as $\frac{1}{2}^+$ states. The logft limits of ≥ 8.1 and ≥ 8.4, respectively, are consistent with second forbidden β^+/EC decay. All transitions placed out of each of these levels are consistent with being $M1$, $E1$, or $E2$ transitions deexciting a $\frac{1}{2}^+$ state.

The eight excited states, 1557.84, 2156.3, 2249.48, 2308.30, 2333.26, 2400.37, 2422.99, and 2429.19 keV, all have logft values ≤ 5.7 and have strong γ branches to the $\frac{1}{2}^-$ ground state. Thus, they are all assigned as definite $\frac{3}{2}^+$ states, consistent with allowed β^+/EC decay from a $\frac{5}{2}^+$ parent and $E1$ γ transitions to a $\frac{1}{2}^-$ state. The $\frac{3}{2}^+$ assignment of the 1557.84-keV level is also consistent with the l value of 2, determined for this level in the (^{3}He, d) reaction study. All transitions placed as deexciting these eight levels are consistent with being $M1$, $E1$, or $E2$ (e.g., none of these levels is observed to decay to any $\frac{9}{2}^+$ states).

The five levels, 987.3, 1327.9, 1441.7, 1750.3, and 1986.3 keV, were all observed in the (^{3}He, d) reaction via strong $l=2$ transitions, limiting their J^π assignment to $\frac{3}{2}^+$ or $\frac{5}{2}^+$. All five levels are observed to decay via strong γ branches to the $\frac{9}{2}^+$ state at 53.2 keV, hence they are all assigned as definite $\frac{5}{2}^+$ states. Their logft values, all ≤ 6.2, are consistent with this assignment.

The excited states at 346.87 and 877.81 keV were observed via $l=1$ transitions in the (^{3}He, d) reaction, and strong $l=2$ transitions in the (p, t) reaction, thus limiting their J^π assignments to $\frac{1}{2}^-$ or $\frac{3}{2}^-$.

The excited state at 433.24 keV was observed in the (^{3}He, d) reaction with an l value of 3 and in the (p, t) reaction with an $l=2$ transfer establishing a $\frac{5}{2}^-$ spin and parity. The observation of strong transitions to the 433.24-keV level from $l=4$ states at 1794.4 and 1923.0 keV are consistent with the assignment of $\frac{5}{2}^-$ and further require that the 1794.4- and 1923.0-keV levels be assigned as definite $\frac{7}{2}^+$ states.

The assignments for three low-lying negative-parity states are derived from the (p, t) reaction study.[25] Assignments of $\frac{7}{2}^-$, $\frac{5}{2}^-$, and $\frac{9}{2}^-$ for the levels at 1023.68, 1042.68, and 1166.27 keV, respectively, are consistent with our data. The 1416-keV level feeds only the ground state and shows little β feeding. It is assigned $\frac{1}{2}^-$, $\frac{3}{2}^-$, or $\frac{5}{2}^-$ on the basis of its strong ground-state branch, although $\frac{1}{2}^+$ cannot be completely ruled out.

The three states at 2276.0, 2314.6, and 2371.74 keV were observed with strong $l=3$ character in the (p, t) study, limiting their spins to $\frac{5}{2}$ or $\frac{7}{2}$ with positive parity. The branch to the $\frac{3}{2}^-$ level at 346.87 keV fixes the spin and parity of the 2276.0-keV state at $\frac{5}{2}^+$. The branches to the $\frac{9}{2}^-$ level at 1166.27 keV fix the spin and parity at $\frac{7}{2}^+$ for the 2314.6- and 2371.74-keV levels.

The three states 2256.5, 2326.13, and 2584.1 keV must be $\frac{3}{2}^+$, $\frac{5}{2}^+$, or $\frac{7}{2}^+$ based on having logft values 5.7, indicating allowed β^+/EC decay. The 2256.5-keV level is assigned as $\frac{5}{2}^+$ based on the observation of strong γ branches to the $\frac{3}{2}^-$ 346.87-keV level and to the $\frac{5}{2}^-$ 433.24-keV level. The 2326.13- and 2584.1-keV levels are assigned as $\frac{5}{2}^+$ based on observed transitions to both $\frac{9}{2}^+$ and $\frac{1}{2}^+$ states.

The states at 1097.1 and 1718.9 keV deexcite via transitions solely to the $\frac{7}{2}^+$ 25.5-keV and the $\frac{9}{2}^+$ 53.2-keV states. They are not directly fed by β^+/EC decay and are not fed from any $\frac{3}{2}^+$ states. They are fed by γ transitions from established $\frac{5}{2}^+$ states. Hence, they are both assigned spin and parity of $\frac{9}{2}^+$. The tentative assignment of $\frac{1}{2}^-$ to the 1097-keV level by Del Vecchio *et al.*[25] is not supported by our results.

The seven levels 2081.7, 2300.4, 2328.03, 2371.74, 2419.2, 2447.20, 2473.0, and 2550.47 keV, all have logft values of 5.6 and are hence limited to J^π values of $\frac{3}{2}^+$, $\frac{5}{2}^+$, or $\frac{7}{2}^+$. Four of these (2081.7, 2419.2, 2447.20, and 2473.0 keV) are further limited to $\frac{5}{2}^+$ or $\frac{7}{2}^+$, as they have strong γ-ray branches to $\frac{9}{2}^+$ states. The 2300.4-keV level is limited to $\frac{3}{2}^+$ or $\frac{5}{2}^+$ by a transition to the $\frac{3}{2}^-$ 346.87-keV level, with the $\frac{3}{2}^+$ assignment favored by the possible placement of the 2300.57-keV transition to the $\frac{1}{2}^-$ ground state. The 2550.47-keV level is limited to $\frac{3}{2}^+$ or $\frac{5}{2}^+$ by a transition to the $\frac{3}{2}^-$ 346.87-keV level. The 2328.03-keV level is limited to $\frac{5}{2}^+$ or $\frac{7}{2}^+$ only if the 2274.83-keV dashed transition may be placed to the $\frac{9}{2}^+$ 53.2-keV level.

In the (^{3}He, d) reaction a strong $l=2$ transition was observed at an energy of 1635 ± 4 keV. We have placed two excited states at 1635.8 keV, one with $J^\pi = \frac{5}{2}^+$ and the other with J^π $\frac{3}{2}^+$, on the basis of transitions to the lower-lying $\frac{9}{2}^+$ states (one of which was confirmed by coincidence data) and a strong transition to the $\frac{1}{2}^-$ ground state. The evidence for the placement of two levels is as follows: (1) a 1071.65- by 538.67-keV coincidence ($1097.1 + 538.7 = 1635.8$ keV), (2) a 1582.56-keV transition placed to the 53.2-keV level ($1582.6 + 53.2 = 1635.8$ keV), (3) a 1635.81-keV transition placed to the $\frac{1}{2}^-$ ground state, (4) a marginal 538.67- by 613.50-keV coincidence, and (5) a marginal 1635.81- by 613.50-keV coincidence. The first two points place an $l=2$ $\frac{5}{2}^+$ level at 1635.8 keV; the third point places an $l=2$ $\frac{3}{2}^+$ level at 1635.8 keV; and the final two points place a transition from the 2249.48-keV level to both the $\frac{3}{2}^+$ and the $\frac{5}{2}^+$ levels at 1635.8 keV. The logft limits for each of these two levels result from using only the transitions that can be unambiguously placed as deexciting one *or* the other level. The logft value of 5.3 is the result of the two levels considered simultaneously and must be regarded as a lower limit for each level.

Eight states are fed directly by the β^+/EC decay, having logft values ranging from 6.0 to 7.4. These are the levels at 1243.41, 1386.3, 1656.2, 1669.5, 1690.7, 1884.9, 1885.9, and 2494.8 keV. All are limited to spin values of $\frac{3}{2}$, $\frac{5}{2}$, or $\frac{7}{2}$, consistent with allowed or first forbidden β^+/EC decay. A J^π value of $\frac{5}{2}^-$ is suggested for the 1243.41-keV level as it deexcites to levels with J^π of $\frac{3}{2}^-$, $\frac{5}{2}^-$, and possibly $\frac{7}{2}^+$, and is fed from $\frac{3}{2}^+$ and $\frac{5}{2}^+$ levels. Values of $\frac{3}{2}^+$, $\frac{3}{2}^-$, and $\frac{5}{2}^+$ cannot be ruled out, but seem unlikely in view of the lack of observed transitions to $\frac{1}{2}^-$ or $\frac{9}{2}^+$ states. The 1386.3 keV level is limited to $\frac{3}{2}^+$ or $\frac{5}{2}^+$ by its l value of 2 determined in the (^{3}He, d) reaction. A $\frac{7}{2}^-$ assignment is suggested for the 1656.2-keV level, as its only transition is to a level of negative parity with $J \geq \frac{3}{2}$. A J^π value of $\frac{5}{2}^+$ is suggested for the 1669.5-keV level on the basis of the relatively low logft value (~6.2), transitions to $\frac{7}{2}^+$ and $\frac{3}{2}^-$ levels, and the lack of an observed transition to the $\frac{1}{2}^-$ ground state. The 1690.7-keV level is suggested to be even parity because of its relatively low logft value (6.3). The strong transition to the $\frac{9}{2}^+$ 53.2-keV state limits it to being $\frac{5}{2}^+$ or $\frac{7}{2}^+$. The levels at 1884.9 and 1885.6 keV are assigned as $\frac{7}{2}^+$ (?) and $\frac{5}{2}^+$ or $\frac{7}{2}^+$, respectively, based on the (^{3}He, d) reaction study that observed an $l=4$ transition with some possible $l=2$ component at 1880 ± 6 keV. The 2494.8-keV level is assigned even parity based on the logft value of 6.0 (indicating a probable allowed β^+/EC transition).

The two states at 1543.1 and 2144.4 were placed on the basis of $l=2$ transitions observed in the (p, t) study indicating $\frac{3}{2}^-$ or $\frac{5}{2}^-$ spin and parity.

The four remaining states (1023.68, 1042.68, 1166.7, and 1416.1 keV), which may have no direct β^+/EC feeding, are all assigned odd parity and $\frac{3}{2} \leq J \leq \frac{7}{2}$, consistent with first forbidden β^+/EC decay and with the lack of any observed transitions to any lower-lying even-parity states. The 1023.68-keV level is suggested to be $\frac{5}{2}^-$ or $\frac{7}{2}^-$ on the basis of a possible (dashed) transition to the $\frac{7}{2}^+$ 25.5-keV state. The observed l value of 4 in

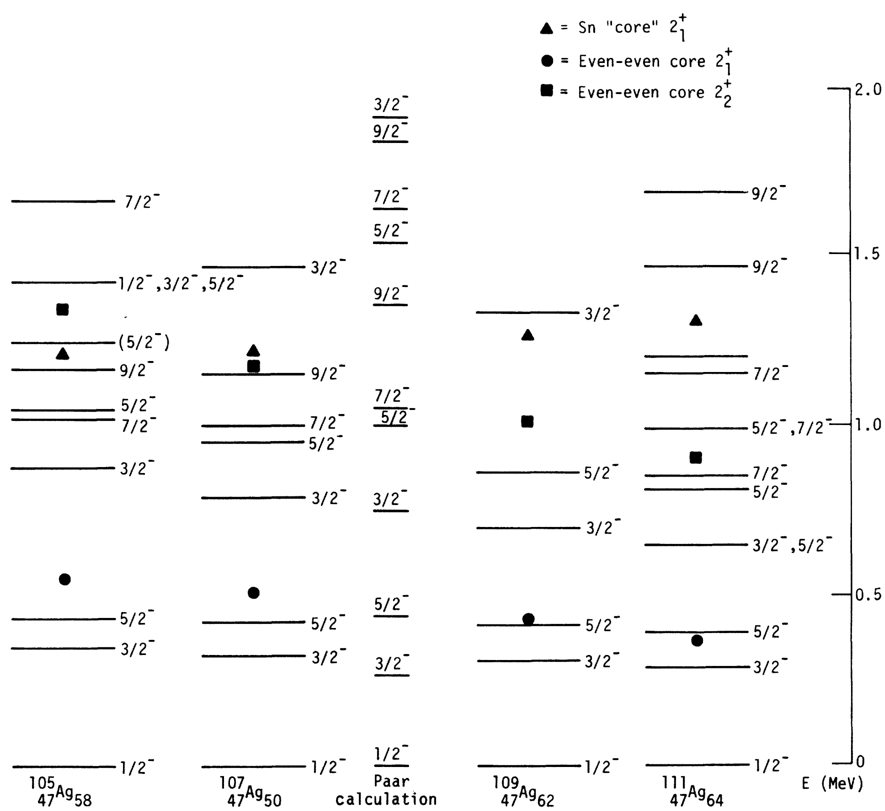


FIG. 4. The systematics of the odd-parity levels observed in the odd-mass silver nuclei. (Refs. 10–12, 14, 15, 32). Also shown are the calculated odd-parity levels (Ref. 1) for an "average" ^{107,109}Ag nucleus and the positions of the phonon excitations in each appropriate palladium core (Refs. 30, 45–51) and each appropriate tin "core" (Refs. 52–54).

the (p, t) reaction requires the $\frac{7}{2}^-$ assignment. The 1166.27 keV state is assigned as $\frac{7}{2}^-$ or $\frac{9}{2}^-$ based on the observed $l = 4$ transition in the (p, t) reaction. As this state was also observed in the (^{3}He, d) reaction, we suggest that the $\frac{7}{2}^-$ assignment is more likely.

The nine additional states listed at the end of Table II and having no definite energy placement are suggested to be positive parity states with $\frac{3}{2} \leq J \leq \frac{7}{2}$. With only a single transition placed out of each of them, their logft values are still ≤ 7.1, suggestive of allowed β^+/EC decay.

V. DISCUSSION

In this investigation of the decay of $\frac{5}{2}^+$ 55.5-min ^{105}Cd, we have examined the character of a large number of excited states in ^{105}Ag. No detailed theoretical calculations of the levels of ^{105}Ag have been reported. The general features of the low-energy (≤ 2 MeV) level structure of ^{105}Ag may be understood, however, by examining the level of energy systematics of the nearby odd-mass nuclei and by comparing the ^{105}Ag level structure with the results of a recent calculation of ^{107,109}Ag levels by Paar,[1] who used a three-proton hole plus quadrupole-vibrator model.

The levels of ^{105}Ag provide an extension of both the isotonic, $N = 58$, and the isotopic, $Z = 47$, odd-A systematics. Detailed calculations of levels other than the $\frac{7}{2}^+$ anomolous coupling state have been reported[1] only for an "average" ^{107,109}Ag nucleus. In Fig. 4, we present the systematics of the odd-parity levels observed in the odd-mass silver nuclei,[10-12,14,15,32] along with the calculated odd-parity levels.[1] Also shown in Fig. 4 are the first and second 2^+ states in each appropriate even-even (palladium) core nucleus,[30,49-51] and the first 2^+ state in each appropriate tin "core".[52-54] The theoretical calculation appears to reproduce the level ordering and spacing very well up to at least 1 MeV. It may be noted, however, that an intermediate-coupling model calculation might well result in an equally good fit to the experimental data. In that model, a $2p_{1/2}$ plus one-phonon doublet with $J^\pi = \frac{3}{2}^-$ and $\frac{5}{2}^-$ is expected near the first-core phonon energy, and five $2p_{1/2}$ plus two-phonon states ranging from $J^\pi = \frac{1}{2}^-$ to $J^\pi = \frac{9}{2}^-$ are expected in the vicinity of the

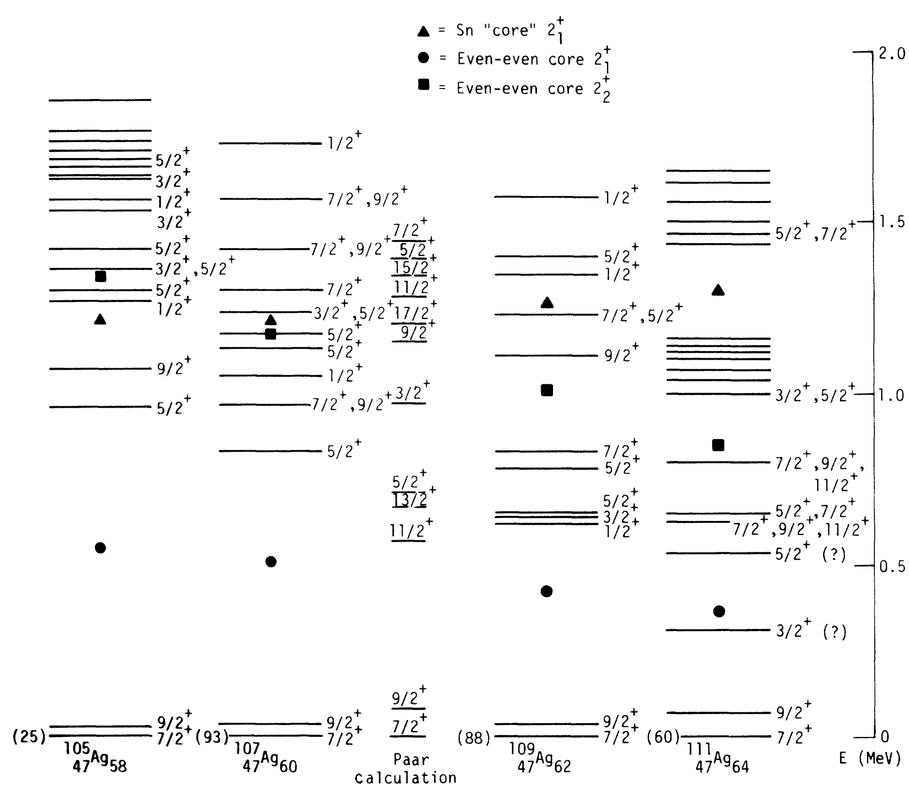


FIG. 5. The low-energy ($\lesssim 2$ MeV) systematics of the even-parity levels observed in the odd-mass silver nuclei (this work and Refs. 11, 12, 15, and 32). Also shown are the calculated even-parity levels (Refs. 1) for an "average" ^{107,109}Ag nucleus and the positions of the phonon excitations in each appropriate palladium core (Refs. 30, 49–51) and each appropriate tin "core" (Refs. 52–54).

two-phonon energy. In fact, the three-hole plus quadrupole model determines configurations for these states that are largely $[(1g_{9/2})^{-2}{}_0 2p_{1/2}{}^{-1}]$ plus one phonon (or two phonons) in character.

The structure of the even-parity levels is quite different from that of the odd-parity level. The odd-mass Ag nuclei are observed to have a very low-lying $\frac{7}{2}^+$ level and a lack of any levels near the Pd core-phonon energy. This is illustrated in Fig. 5, where we present the low-energy systematics of the even-parity levels in the odd-mass silver nuclei[11,12,15,32] along with the levels calculated for an "average" ^{107,109}Ag nucleus. As in Fig. 4, the Pd and Sn core-quadrupole vibration excitations are also indicated. The energy scale has been adjusted so that zero energy corresponds to the $\frac{7}{2}^+$ anomolous coupling state. It is clear from the lack of states near the Pd core one-phonon excitation energy that an intermediate coupling-model calculation would fail to account for the observed level structures. The three-hole plus phonon model, however, appears to explain the two major features of the level structures, namely, the low-lying $\frac{7}{2}^+$ anomolous coupling state, and is the large gap between the $\frac{9}{2}{}_1^+$ level and the next even-parity level, generally a $\frac{5}{2}^+$ state. This latter characteristic is particularly evident in ^{105}Ag and ^{107}Ag and becomes less apparent as the phonon energy decreases, reflecting a "softer" nucleus. All of the possible states resulting from a three-hole plus quadrupole-vibration calculation have not been calculated, therefore it is not possible to make a more detailed comparison between the experimental data and the theoretical predictions in the case of the even-parity excited states.

Because of its low energy, the $\frac{7}{2}^+$ level cannot be explained as being a single-proton-hole shell-model state and has in fact been interpreted as being a three-proton-hole state. This was first suggested by Talmi and Unna,[55] who proposed the configuration $(lg_{9/2})^{-3}{}_{7/2}$ for the state. In ^{105}Ag, experimental evidence supporting this configuration is provided by the measured magnetic moment of the $\frac{7}{2}^+$ state of ± 4.31 nuclear magnetons.[56] It has been noted that, based on the empirical magnetic moment of $+5.53\mu_N$ for a $(\pi 1g_{9/2})^{-1}$ configuration determined from the odd-A indium nuclei, a pure $(1g_{9/2})^{-3}{}_{7/2}$ state is expected to have a magnetic moment of $+4.30\mu_N$. Recent theoretical calculations of the odd-mass silver nuclei by Paar[1] using a three-hole plus quadrupole-vibration model and of odd-mass silver, rhodium, and technetium nuclei by Kuriyama, Marumori, and Matsuyanagi[3,4] using a dressed three-quasiparticle model have also predicted the $\frac{7}{2}^+$ state to be mainly $(1g_{9/2})^{-3}{}_{7/2}$. In both calculations, the explicit treatment of the Pauli principle in the valence shell results in the $[(J^{-2})_2 J^{-1}]$ multiplet being split, with the $J-1$ coupling being brought down and the other four couplings ($J-2$, J, $J+1$, and $J+2$) being raised. This effect is particularly strong in the case of the $1g_{9/2}$ orbital, as the configuration $(\pi 1g_{9/2})^{-2}{}_2$ makes a large contribution to the one-phonon excitation in this region. Thus, a low-lying $\frac{7}{2}^+$ state with the configuration $(1g_{9/2})^{-3}{}_{7/2}$ is predicted for Tc, Rh, and Ag nuclei.

The calculations shown in Fig. 5 exhibit no $\frac{1}{2}^+$ states below 1500 keV. Two $\frac{1}{2}^+$ states were observed in the (^{3}He, d) studies and confirmed in our work at 1294 and 1586 keV. The transfer strength to the lower state was surprisingly large, as the $\frac{1}{2}^+$ single-particle orbital lies across the shell at $Z=50$. Moreover, $\frac{1}{2}^+$ states with large transfer strength are also observed in ^{107}Ag, ^{109}Ag, and ^{111}Ag in radioactive decay studies. Systematically, these states show a sharp drop with increasing neutron number. The relatively intense $E1$ branches discussed by Aras and Walters[57] in ^{105}Rh to the lowest $\frac{1}{2}^-$ and $\frac{3}{2}^-$ states are consistent with the strong transfer strength. In the odd-mass Ag nuclei, $\frac{3}{2}^+$ states may be identified as exhibiting similar properties. In ^{111}Ag, the lowest $\frac{1}{2}^+$ state has been suggested to be a $\frac{1}{2}^+$ [411] deformed state with a Coriolis decoupled band build on it.[15] To establish deformed character for such a $\frac{1}{2}^+$ state, a long lifetime comparable to those observed in In would have to be measured.[40] In Fig. 6, we show the level systematics below 1 MeV for the $N=58$ odd-mass nuclei from $Z=41$ to $Z=47$.[57-60] Also shown is the position of the one-phonon excitation in each appropriate even-even core ($Z-1$, $A-1$) and in the Sn core (^{108}Sn) in the case of ^{105}Ag.[53,61-64] The unfilled proton-shell-model orbitals for these odd-A nuclei are the $2p_{1/2}$ and $1g_{9/2}$ orbitals. Thus, the low-lying $\frac{1}{2}^-$ and $\frac{9}{2}^+$ states may be understood as being single-proton (quasiproton) states. The $\frac{1}{2}^-$ state fails to become the ground state in ^{103}Rh and ^{105}Ag as a consequence of the pairing energy being greater in the higher-J $1g_{9/2}$ orbital.[65] The low-lying $\frac{3}{2}{}_1^-$ and $\frac{5}{2}{}_1^-$ states may be explained as being the states expected from the coupling of the $2p_{1/2}$ single-proton state with the one-phonon core excitation. The systematics of the $\frac{5}{2}^+$ and $\frac{7}{2}{}_1^+$ states are of special interest, however. The $\frac{5}{2}{}_1^+$ level drops dramatically to just 15.6 keV in ^{101}Tc. As the first $\frac{7}{2}^+$ state in ^{99}Nb is unknown, the fall of the $\frac{7}{2}{}_1^+$ level is not shown. However, the first $\frac{7}{2}^+$ state in $^{107}_{49}$In$_{58}$ does not occur until at least 1 MeV.[66] The behavior of these states cannot be explained in terms of a quasiparticle-plus-phonon model or an intermediate coupling model. The nearest $\frac{5}{2}^+$ and $\frac{7}{2}^+$ single-proton orbitals are located in the next major shell, and no particle-phonon coupling calculation sufficiently

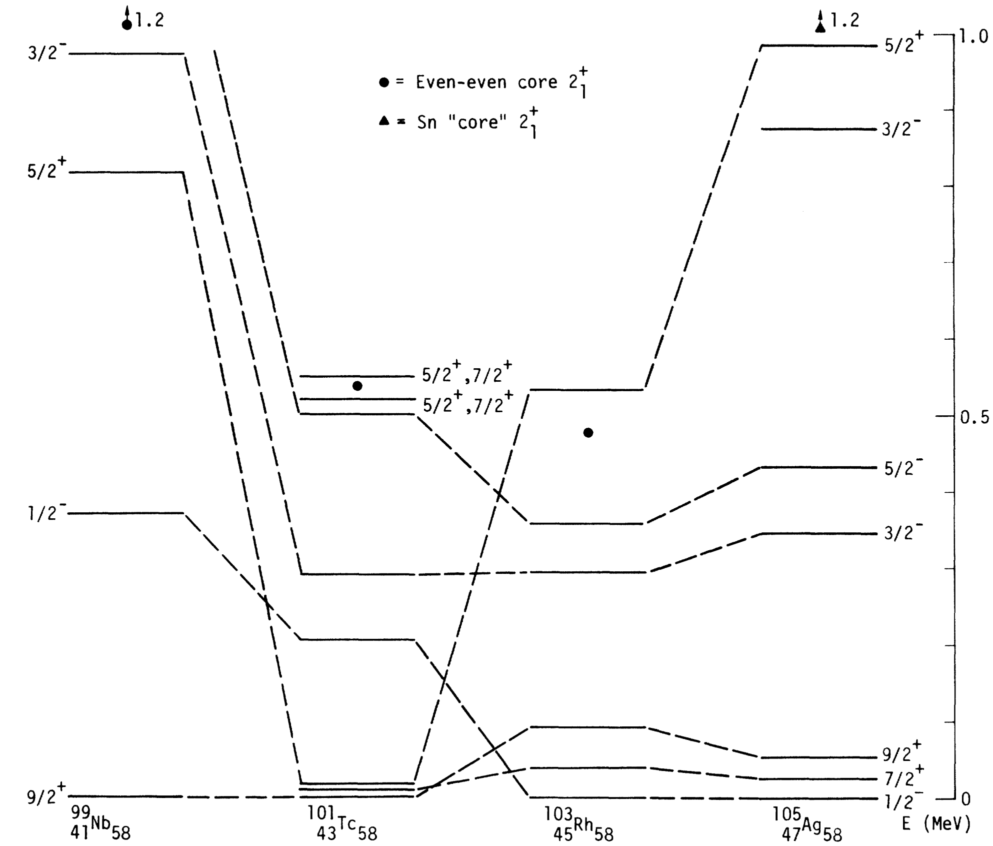


FIG. 6. The low-energy (≲1 MeV) level systematics of the $N = 58$ odd-mass nuclei (this work and Refs. 39, 58, 60). Also shown is the position of the one-phonon excitation in each appropriate even-even core (Refs. 53, 61–63, 71).

brings down the $\frac{5}{2}^+$ state in Tc or the $\frac{7}{2}^+$ state in Tc, Rh, and Ag.[65] The $\frac{7}{2}^+$ level is just the three-proton-hole $(1g_{9/2})^{-3}$ state described above. The low-lying $\frac{5}{2}^+$ state in Tc (and Rh) has not been treated in detail, although Kuriyama *et al.*[3,4] have suggested that the five quasiparticle $[(J^2)_2(J^2)_2J']$ configuration resulting in the lowering of the $J-2$ coupling might be responsible. Kuriyama *et al.* have also demonstrated[4] that the coupling between a $[(J^{-2})_2J^{-1}]$ configuration and the single quasiparticle $J-2$ state from the next shell $(2d_{5/2})$ results in the lowering of the $J-2$ state.

In the high-energy level structure at ^{105}Ag, the major feature of interest is the strong EC feeding to many even-parity states. We have in fact observed major electron capture branches ($\log ft \lesssim 5.5$) from $\frac{5}{2}^+$ ^{105}Cd to 17 levels in ^{105}Ag between 2300 and 2600 keV. In the cases of three levels, in particular at 2326.13, 2333.26, and 2550.47 keV, the decay branches are especially strong, having $\log ft$ values of 4.2, 4.5, and 4.9, respectively. The shell-model valence states for ^{105}Cd and ^{105}Ag and $1f_{7/2}$, $2p_{3/2}$, and $1g_{9/2}$ for protons, and $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$, and $1h_{11/2}$ for neutrons. The only single-nucleon EC transition that is not l forbidden is $\pi 1g_{9/2}$ to $\nu 1g_{7/2}$. In ^{111}Sn decay this transition has been observed to have a $\log ft$ of 4.8,[33] and the β^- transition in ^{117}In decay, $\nu 1g_{7/2}$ to $\pi 1g_{9/2}$, has been observed to have a $\log ft$ of 4.4.[67] The electron capture decay data for ^{105}Cd, therefore, suggest that the strongly fed states ($\log ft \lesssim 5.5$) above the neutron pairing energy (~2.1 MeV) are principally one-proton two-neutron states. The EC-decay mechanism would then involve the transition from $\frac{5}{2}^+$ ^{105}Cd, assumed to be in the $[\pi(1g_{9/2})^2{}_0\nu,\ (2d_{5/2})]_{5/2}$ configuration, to one of the many $\frac{3}{2}^+$, $\frac{5}{2}^+$, or $\frac{7}{2}^+$ states in ^{105}Ag resulting from the configuration

$$[\pi 1g_{9/2}{}^{-1}(\nu_1\ 2d_{5/2},\ \nu_2\ 1g_{7/2})_{1,2,3,4,5,6}]_{3/2,\ 5/2,\ 7/2}.$$

In the ^{104}Pd core, a large number of even-parity states with $1 < J < 6$ have been observed in the vicinity of 1.8 to 2.7 MeV, and several of these have been suggested as candidates for two quasiparticle states.[68–71] It seems likely that several of these are two-neutron states, and that the $\pi\nu^2$ states in ^{105}Ag may be explained by a coupling between the $1g_{9/2}$ hole state in ^{105}Ag and the two-neutron states in the ^{104}Pd core.

The strong β^+/EC-decay branch from $\frac{5}{2}^+$ ^{105}Cd to the $\frac{7}{2}^+$ anomalous coupling state, with $\log ft = 5.4$, is somewhat difficult to understand in view of the predicted $(1g_{9/2})^{-3}{}_{7/2}$ configuration for the $\frac{7}{2}^+$ state. The single-nucleon β^+/EC transition, $\pi 1g_{9/2}$ to $\nu 2d_{5/2}$, is second forbidden, leading one to expect a much higher $\log ft$ value (≥ 10). In light of the preceding discussion of β^+/EC-decay mechanisms it seems likely that this transition must involve a $\pi 1g_{9/2}$ to $\nu 1g_{7/2}$ transition. Thus, the ground state of ^{105}Cd must have some amount of the seniority-three configuration

$$[(\pi 1g_{9/2})^2{}_0(\pi 1g_{9/2})^{-2}{}_2\nu 1g_{7/2}]_{5/2}$$

mixed into it. The $\pi 1g_{9/2}$ to $\nu 1g_{7/2}$ β^+/EC transition would then result in leaving ^{105}Ag in the

$$[(\pi 1g_{9/2})^{-2}{}_2(\pi 1g_{9/2})^{-1}(\nu 1g_{7/2})^2{}_0]_{7/2}$$

configuration, the proton part of which is just the $(1g_{9/2})^{-3}{}_{7/2}$ configuration suggested for the $\frac{7}{2}^+$ anomolous-coupling state. If the "bare" $\pi 1g_{9/2}$ to $\nu 1g_{7/2}$ transition is assumed to have a $\log ft$ value of 3.8–4.0, then the observed $\log ft$ value of 5.4 could be accounted for by a mixing of only 2.5–4.0% seniority-three configuration into the ^{105}Cd ground state. This is not unreasonable in view of the expected occupancy of the $\nu 1g_{7/2}$ orbital in $N=57$ nuclei (^{105}Cd), and in view of the predicted prevalence of the $(\pi 1g_{9/2})^{-2}{}_2$ two-proton hole configuration in the silver nuclei.

The combination of our data and the results of the (p, t) studies[25] permit the identification of the states whose configurations are $(p_{1/2}\otimes 3^-)_{5/2^+, 7/2^+}$. Two such $\frac{7}{2}^+$ states were observed with strong EC feeding and low $\log ft$ values at 2314.6 and 2371.74 keV. Only a single $\frac{5}{2}^+$ state is observed at 2276.0 keV and it is fed in very low intensity in EC decay. These results are easily described by assuming that the $\frac{5}{2}^+$state has a nearly pure $(p_{1/2}\otimes 3^-)_{5/2^+}$ configuration whereas the $(p_{1/2}\otimes 3^-)_{7/2^+}$ configuration is mixed with a state (or states) having appropriate $\pi\nu^2$ character. The $\pi\nu^2$ part gives rise to the rapid EC feeding and strong γ-ray branching to the positive-parity levels (e.g., 1794.4 keV), whereas the $(p_{1/2}\otimes 3^-)$ part permits the strong $l=3$ branches in the (p, t) reaction and the $E1$ γ-ray branches to the negative-parity levels (e.g., 433.24 and 1166.26 keV). The $E1$ decay would be the decay of the core 3^- to the core 2^+ state. For the $\frac{5}{2}^+$ state with minimal $\pi\nu^2$ character, we see only the $E1$ branch to the 346.87-keV $\frac{3}{2}^-$ state whose configuration is largely $p_{1/2}\otimes 2^+$.

In conclusion, it is clear that a three-hole model of some type is necessary to explain the $\frac{7}{2}^+$ anomalous coupling state observed in the odd-mass silver nuclei. The three-hole plus quadrupole-vibrator model of Paar successfully explains many of the characteristics of the low-energy level structures in the odd-mass silver nuclei. However, further theoretical calculations are needed to make more detailed comparison between theory and experiment. More detailed level calculations using the dressed three-quasiparticle model of Kuriyama *et al.*[3-7] are also needed. Having a large number of well-characterized excited states, the level structure of ^{105}Ag can now provide a good test of this theoretical work. It should be noted, however, that for levels above 2 MeV any theoretical model must include $\pi\nu^2$ configurations among its basis states to explain all of the observed even-parity levels in ^{105}Ag. This cannot be done in the three-hole plus quadrupole-vibrator model. On the other hand, the dressed three-quasiparticle model already does this to the extent of including ν^2 configurations coupling to 0^+ and 2^+. This model, however, must be extended to treat explicitly five quasiparticles to deal with two-phonon vibrational states.

Note Added: Recent studies[72] of the ^{105}Pd (p, n) ^{105}Ag reaction have come to our attention since this article was submitted for publication. Their observations are consistent with ours and permit the additional assignments of γ-rays that we observe. They place a negative parity level at 1400.2 keV that feeds the 433-keV $\frac{5}{2}^-$ level by a 967.1-keV γ ray. We observed a γ ray at that energy but could not place it. They propose five new positive-parity levels at 1871.2, 1571.8, 1281.8, 917.2, and 668.6. We do not observe any of the γ rays associated with the 1871.2- or 1571.8 keV levels. We observe transitions at all three of the energies (613.2, 1228.5, and 1256.3 keV) associated with the decay of the 1281.8-keV level, but place them elsewhere. The 917.2-keV level decays by γ rays at 864.0 and 248.6 keV, that we do not observe although the latter is near a γ ray at 249.41 keV. The 668.6-keV level decays by a single 615.4-keV γ ray to the $\frac{9}{2}^+$ level at 53.2 keV. We observe a multiplet at 613–617 keV that might readily obscure any such weak γ ray. The 668.6- and 917.2-keV levels are good candidates for the $\frac{11}{2}^+$ and $\frac{13}{2}^+$ members, respectively, of the $g_{9/2}\otimes 2_1^+$ multiplet. We observe a γ ray at 1371.41 ± 0.11 keV that could populate the 668.6-keV level from the $\frac{7}{2}^+$ level at 1986.3 keV, which is consistent with a possible $\frac{11}{2}^+$ assignment for the 6686.6-keV level. The positions of these two levels agree quite well with the $\frac{11}{2}^+$ and $\frac{13}{2}^+$ states predicted by Paar (see Fig. 5).

†Work performed under the auspices of the U.S. Energy Research and Development Administration.

*Associated Western Universities Fellow to Lawrence Livermore Laboratory, 1975. Present address: Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87104.

‡Consultant to Lawrence Livermore Laboratory. Permanent address: Chemistry Department, University of Maryland, College Park, Maryland. Work presented in partial fulfillment of the requirements for the Ph.D. degree.

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