PHYSICAL REVIEW C VOLUME 15, NUMBER 3 MARCH 1977

Decay of mass-separated ^{137}Xe to levels in the $N = 82$ nucleus ^{137}Cs†

W. R. Western, John C. Hill, W. L. Talbert, Jr., and W. C. Schick, Jr.*
Ames Laboratory-ERDA and Department of Physics, Iowa State University, Ames, Iowa 50011
(Received 9 December 1976)

The γ rays following the β decay of mass-separated ^{137}Xe to levels in ^{137}Cs have been studied. Of 94 γ rays observed, 83 were placed in a ^{137}Cs level scheme consisting of 34 excited states up to 3976 keV. The results are compared with levels from single-proton transfer reactions and shell-model calculations.

[RADIOACTIVITY ^{137}Xe [from ^{235}U(n,f)]; measured E_γ, I_γ, $\gamma\gamma$-coin. Ge(Li) detectors; ^{137}Cs deduced levels, J, π, logft. Mass-separated ^{137}Xe activity.]

I. INTRODUCTION

The nucleus ^{137}Cs is of interest since it contains a closed shell of 82 neutrons and five protons beyond the magic number $Z=50$. For this nucleus excited states below 2 MeV should be explainable in terms of the excitations of the five protons outside of the doubly-magic ^{132}Sn core, to provide a good test of multiparticle shell-model calculations in the $N=82$ region.

The decay of ^{137}Xe to levels in ^{137}Cs was first observed in 1943 by Seelmarn-Eggebert and Born.[1] The first comprehensive γ-decay study using Ge(Li) detectors was carried out by Holm[2] who also measured the ^{137}Xe half-life to be 3.88 ± 0.03 min. Recently Monnand *et al.*[3] presented a decay scheme for ^{137}Xe which placed 55 γ rays in a level scheme for ^{137}Cs containing 23 excited states.

Levels in ^{137}Cs have also been studied by Wildenthal, Newman, and Auble[4] who used single-proton transfer reactions on ^{136}Xe and ^{138}Ba targets to identify the single-particle proton states. The γ rays depopulating the first two ^{137}Cs excited states were observed by Lucas *et al.*[5] after μ^- capture to ^{138}Ba. Experimental data on ^{137}Xe decay and levels in ^{137}Cs have recently been compiled by the Nuclear Data Group.[6] Shell-model calculations for ^{137}Cs up to 3 MeV have been performed by Heyde and Waroquier[7] and Wildenthal.[8]

The work reported here on the decay of ^{137}Xe was undertaken to clarify discrepancies in earlier ^{137}Xe decay studies and to provide reliable level information on ^{137}Cs for comparison with shell-model calculations on the $N=82$ isotones.

II. EXPERIMENTAL METHODS

Sources of mass-separated ^{137}Xe were produced by the TRISTAN on-line isotope separator facility at the Ames Laboratory research reactor. The details of this system have been described elsewhere.[9] For singles measurements the $A=137$ ion beam from TRISTAN was collected on a movable tape in the moving tape system described in Ref. 9. A Ge(Li) detector with an efficiency of about 10% viewed the point of deposit. In typical runs sufficient activity was obtained using about a 10-sec collection time. After collection the activity was counted for about 90 sec. The tape was then moved to minimize contamination from long-lived activities.

A representative singles spectrum from 60 to 1620 keV was collected for a 16-h period and is shown in Fig. 1. The only impurities observed were background lines from ^{41}Ar, ^{60}Co, and ^{137}Cs. A second spectrum was collected using an absorber between the source and the detector which consisted of 7 mm of Pb and 2 mm of Cd. This was necessary in order to suppress counts from the strong 456-keV γ ray and enhance weak γ rays above 3 MeV. The collection time for the absorber spectrum was 42 hours. The region between 1.2 and 4.2 MeV is shown in Fig. 2. The strongest transitions in the decays of ^{140}La, ^{138}Xe, and ^{138}Cs were observed as background contamination.

A total of 94 γ rays were assigned to ^{137}Xe decay. Transition energies and intensities were determined using γ rays from the standard calibration sources ^{197}Ir, ^{198}Au, and ^{56}Co. A summary of the transition energies and intensities for ^{137}Xe decay obtained in this work is given in Table I. Our results are also compared with those of Monnand *et al.*[3] and Holm,[2] and upper intensity limits are given for γ rays observed in earlier work[2,3] but not seen by us. Three transitions reported in earlier work[3] were interpreted by us to be escape peaks from higher energy γ rays. We interpreted the 934-keV peak to be a singlet but observed doublets corresponding to peaks reported[3] earlier at 1234 and 2099 keV. The peak at 1461 keV contains a 15% contribution from ^{40}K in the background.

Coincidence measurements were made using two Ge(Li) detectors of approximately 10% efficiency in 180° geometry. Coincidence timing was derived from constant-fraction techniques, and a total ac-

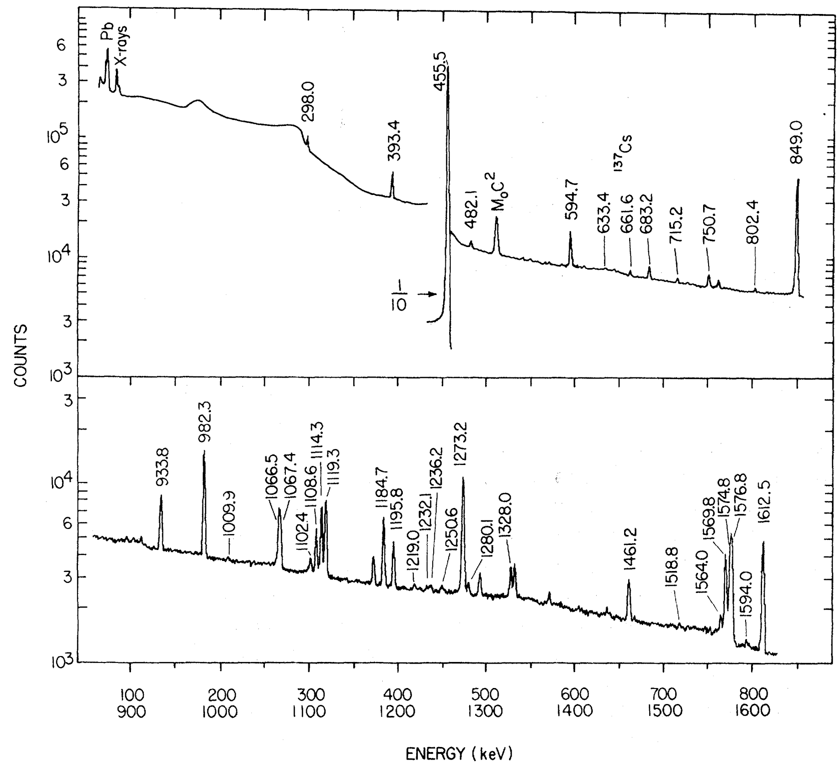

FIG. 1. γ-ray spectrum of ^{137}Xe decay from 60 to 1620 keV.

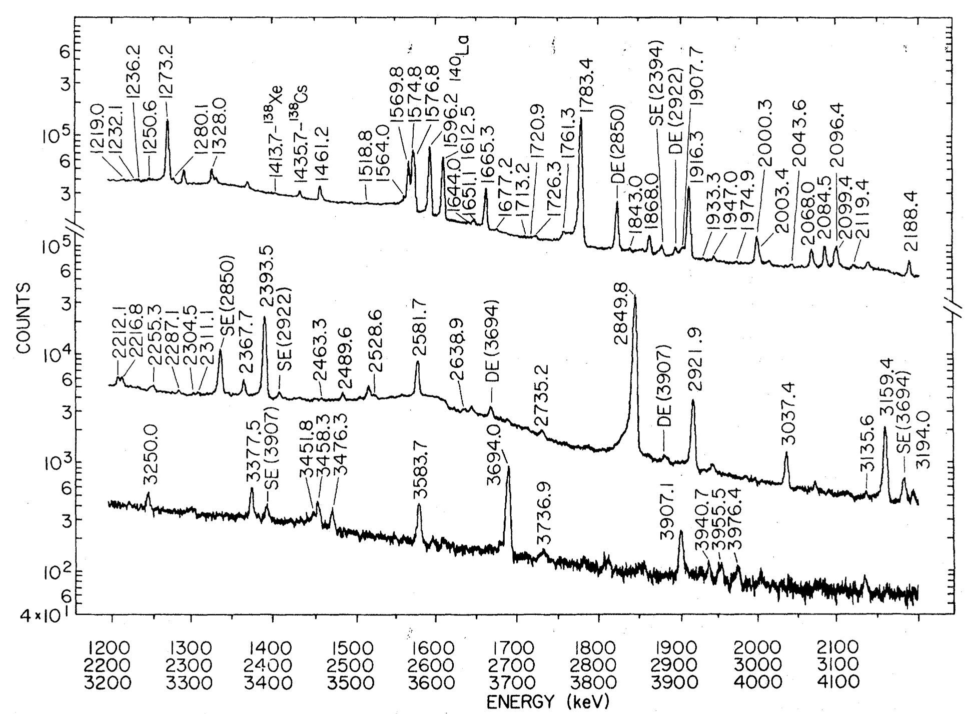

FIG. 2. γ-ray spectrum of ^{137}Xe decay from 1.2 to 4.2 MeV. An absorber consisting of 7 mm of Pb and 2 mm of Cd was used.

TABLE I. γ-ray transitions observed in the decay of ^{137}Xe.

Energy [a] (keV)	Relative intensity [a]	Energy [b] (keV)	Relative intensity [b]	Energy [c] (keV)	Relative intensity [c]	Placement, this work
298.00 ± 0.07	3.8 ± 0.3	297.6 ± 0.6	3.0			1868-1570
393.35 ± 0.06	4.5 ± 0.3	393.5 ± 0.3	4.3	394	5.7	849-456
455.51 ± 0.04	1000 [d]	455.45 ± 0.10	1000 [d]	456	1000 [d]	456-0
482.14 ± 0.12	0.48 ± 0.10	481.9 ± 0.3	0.5			2850-2368
	<0.05	526.8 ± 0.5	0.2			
DEP(1570)		547.3 ± 0.5	~0.1			
	<0.04	584.5 ± 0.5	<0.1			
594.70 ± 0.06	2.7 ± 0.3	594.5 ± 0.2	2.7	595	3	1868-1273
633.4 ± 0.5	0.08 ± 0.04					2850-2217
DEP(1665)		644.0 ± 1.0	0.2			
683.2 ± 0.1	0.65 ± 0.07	683.0 ± 0.3	0.7	684	0.7	1868-1185
	<0.04	700.0 ± 1.0	<0.1			
715.2 ± 0.2	0.21 ± 0.05	715.4 ± 0.5	~0.1			1564-849
750.65 ± 0.1	0.67 ± 0.07	750.6 ± 0.3	0.8			2850-2099
802.4 ± 0.4	0.13 ± 0.04	802.0 ± 1.0	<0.1			1651-849
848.95 ± 0.06	20 ± 1	849.0 ± 0.2	22.8	849	21.7	849-0
	<0.04	865.0 ± 1.0	~0.1			
933.82 ± 0.06	2.7 ± 0.2	{933.3 ± 0.3	0.7}	934	2.3	2850-1916
		934.4 ± 0.3}	2.3}			
	<0.04	954.0 ± 1.0	<0.1			
982.25 ± 0.05	6.7 ± 0.4	982.4 ± 0.2	7.3	982	7.3	2850-1868
1009.9 ± 0.2	0.13 ± 0.03	1007.5 ± 0.6	<0.1			Unplaced
	<0.04	1024.0 ± 0.6	<0.1			
	<0.04	1037.4 ± 0.5	<0.1			
1066.5 ± 0.2	1.74 ±0.3	1066.6 ± 0.3	2.0	1068	2.7	2850-1783
1067.4 ± 0.2	1.57 ± 0.3	1067.8 ± 0.3	1.7			1916-849
	<0.03	1097.0 ± 0.5	~0.1			
1102.42 ± 0.10	0.53 ± 0.05	1102.4 ± 0.4	0.6			3952-2850
1108.63 ± 0.06	1.64 ± 0.15	1108.6 ± 0.4	1.8	1107	2.3	1564-456
1114.32 ± 0.06	2.96 ± 0.2	1114.5 ± 0.3	3.3}	1117	6.7	1570-456
1119.33 ± 0.06	3.43 ± 0.2	1119.5 ± 0.3	3.9}			1575-456
	<0.03	1139.5 ± 1.0	~0.1			
1184.70 ± 0.06	2.7 ± 0.3	1184.6 ± 0.3	2.9	1185	2.7	1185-0
1195.75 ± 0.06	1.54 ± 0.1	1195.5 ± 0.3	1.7	1197	2.3	1651-456
1219.0 ± 0.4	0.09 ± 0.02	1219.0 ± 0.6	~0.1			2068-849
1232.1 ± 0.7	0.05 ± 0.02}	{1234.0 ± 1.0	~0.1			2796-1564
1236.2 ± 0.4	0.11 ± 0.02}					3104-1868
1250.6 ± 0.4	0.21 ± 0.03	1251.0 ± 1.0	~0.1			2099-849
1273.23 ± 0.1	7.3 ± 0.7	1273.2 ± 0.2	7.5	1275	8.3	1273-0
1280.05 ± 0.15	0.30 ± 0.03	1280.0 ± 0.6	0.2			2850-1570
1327.98 ± 0.06	0.94 ± 0.08	1328.0 ± 0.5	1.0	1330	0.7	1783-456
1461.16 ± 0.2	0.55 ± 0.07					1916-456
1518.8 ± 0.5	0.06 ± 0.02	1519.0 ± 1.0	0.2			2368-849
	<0.02	1529.0 ± 1.0	0.1			
1564.0 ± 0.2	0.32 ± 0.04	1564.0 ± 1.0	0.3			1564-0
1569.77 ± 0.07	2.74 ± 0.2	1569.8 ± 0.3	3.0			1570-0
1574.83 ± 0.15	2.3 ± 0.3	1575.0 ± 0.4	1.7}	1576	5.7	1575-0
1576.75 ± 0.10	3.3 ± 0.3	1576.9 ± 0.4	3.9}			2850-1273
1594.0 ± 0.6	0.10 ± 0.02	1594.0 ± 0.6	0.1			3377-1783
1612.52 ± 0.06	4.0 ± 0.3	1612.6 ± 0.3	4.5	1615	5.3	2068-456
1644.0 ± 0.8	0.028 ± 0.015					2099-456
1651.14 ± 0.2	0.14 ± 0.02	1650.7 ± 0.7	~0.1			1651-0
1665.30 ± 0.07	1.7 ± 0.1	1665.4 ± 0.3	2.0	1668	2.7	2850-1185
1677.2 ± 0.6	0.032 ± 0.013					Unplaced
1713.2 ± 0.8	0.024 ± 0.015					Unplaced
1720.9 ± 0.6	0.035 ± 0.015					3928-2217
1726.3 ± 0.3	0.077 ± 0.013					3377-1651

TABLE I. (*Continued*)

Energy [a] (keV)	Relative intensity [a]	Energy [b] (keV)	Relative intensity [b]	Energy [c] (keV)	Relative intensity [c]	Placement, this work
1761 ± 0.3	0.19 ± 0.05	1761.0 ± 1.0	0.2			2217-456
1783.43 ± 0.06	13.3 ± 0.6	1783.4 ± 0.2	15.3	1784	16.0	1783-0
1843.0 ± 0.4	0.046 ± 0.012	1843.0 ± 1.0	<0.1			Unplaced
	<0.02	1857.6 ± 1.0	<0.1			
1867.96 ± 0.08	0.52 ± 0.05	1868.0 ± 0.4	0.6			1868-0
1907.7 ± 0.2	0.17 ± 0.02					3824-1916
1916.31 ± 0.08	3.1 ± 0.4	1916.5 ± 0.3	3.2	1917	3.7	1916-0
1933.3 ± 0.4	0.043 ± 0.012					3584-1651
1947.0 ± 0.2	0.085 ± 0.011	1947.0 ± 1.0	<0.1			2796-849
1974.9 ± 0.5	0.038 ± 0.012					3159-1185
2000.3 ± 0.2	0.57 ± 0.06	2001.0 ± 0.5	0.7			2849-849
2003.4 ± 0.3	0.21 ± 0.04					3787-1783
2043.6 ± 0.3	0.057 ± 0.012	2043.2 ± 1.0	<0.1			Unplaced
2068.0 ± 0.2	0.33 ± 0.03	2068.0 ± 0.4	0.4			2068-0
2084.47 ± 0.10	0.44 ± 0.03	2084.5 ± 0.3	0.5			3952-1868
2096.4 ± 0.3	0.23 ± 0.03 }	2098.6 ± 0.3	0.6			2945-849
2099.42 ± 0.15	0.43 ± 0.04 }					2099-0
2119.4 ± 0.4	0.055 ± 0.012					Unplaced
2188.44 ± 0.10	0.26 ± 0.03	2188.6 ± 0.4	0.4			3037-849
2212.1 ± 0.2	0.13 ± 0.02	2212.8 ± 0.6	~0.1			3787-1575
2216.8 ± 0.4	0.076 ± 0.03					2217-0
2255.3 ± 0.3	0.08 ± 0.01	2255.5 ± 1.0	~0.1			3104-849
2287.1 ± 0.4	0.045 ± 0.008					3938-1651
2304.5 ± 0.8	0.018 ± 0.008					3955-1651
2311.1 ± 0.5	0.031 ± 0.008					3584-1273
2367.65 ± 0.2	0.21 ± 0.03	2368.0 ± 0.6	0.2			2368-0
2393.53 ± 0.15	2.6 ± 0.2	2393.6 ± 0.3	2.9	2396	3.3	2849-456
2463.3 ± 0.7	0.023 ± 0.009					3737-1273
2489.6 ± 0.2	0.088 ± 0.010	2489.4 ± 1.0	<0.1			2945-456
2528.6 ± 0.6	0.047 ± 0.011					3377-849
2581.71 ± 0.1	0.75 ± 0.07	2581.8 ± 0.3	0.8			3037-456
2638.9 ± 0.7	0.029 ± 0.011					3824-1185
2735.2 ± 0.4	0.044 ± 0.009					3584-849
2849.80 ± 0.1	5.9 ± 0.3	2850.0 ± 0.2	7.6	2852	8.7	2850-0
2921.9 ± 0.2	0.57 ± 0.05	2922.1 ± 0.3	0.7	2924	1.0	3377-456
3037.4 ± 0.2	0.14 ± 0.02	3037.4 ± 0.6	0.2			3037-0
3135.6 ± 0.7	0.012 ± 0.005					Unplaced
3159.4 ± 0.2	0.38 ± 0.04	3159.6 ± 0.6	0.5	3162	0.3	3159-0
3194.0 ± 0.4	0.029 ± 0.006	3195.5 ± 1.0	<0.1			Unplaced
3250.0 ± 0.4	0.034 ± 0.006	3250.3 ± 1.0	<0.1			Unplaced
3377.4 ± 0.2	0.064 ± 0.008	3377.8 ± 0.8	<0.1			3377-0
SEP(3907)		3396.0 ± 1.5	<0.1			
3451.8 ± 0.8	0.015 ± 0.007					3907-456
3458.3 ± 0.4	0.041 ± 0.007	3458.5 ± 1.0	<0.1			Unplaced
3476.3 ± 0.4	0.028 ± 0.006	3475.5 ± 1.5	<0.1			Unplaced
3583.7 ± 0.3	0.063 ± 0.009	3583.0 ± 2.0	0.1			3584-0
3694.0 ± 0.3	0.20 ± 0.02	3693.5 ± 1.0	0.3	3697	0.3	3694-0
3736.9 ± 0.7	0.010 ± 0.003					3737-0
	<0.003	3797.0 ± 3.0	<0.1			
3907.1 ± 0.4	0.043 ± 0.007	3907.5 ± 3.0	<0.1	3914		3907-0
3940.7 ± 0.9	0.008 ± 0.004					3941-0
3955.5 ± 0.8	0.011 ± 0.004					3955-0
3976.4 ± 0.8	0.010 ± 0.004					3976-0

[a] Results from this work.
[b] Results from Ref. 3.
[c] Results from Ref. 2.
[d] Intensity normalized to 1000 for the 456-keV transition.

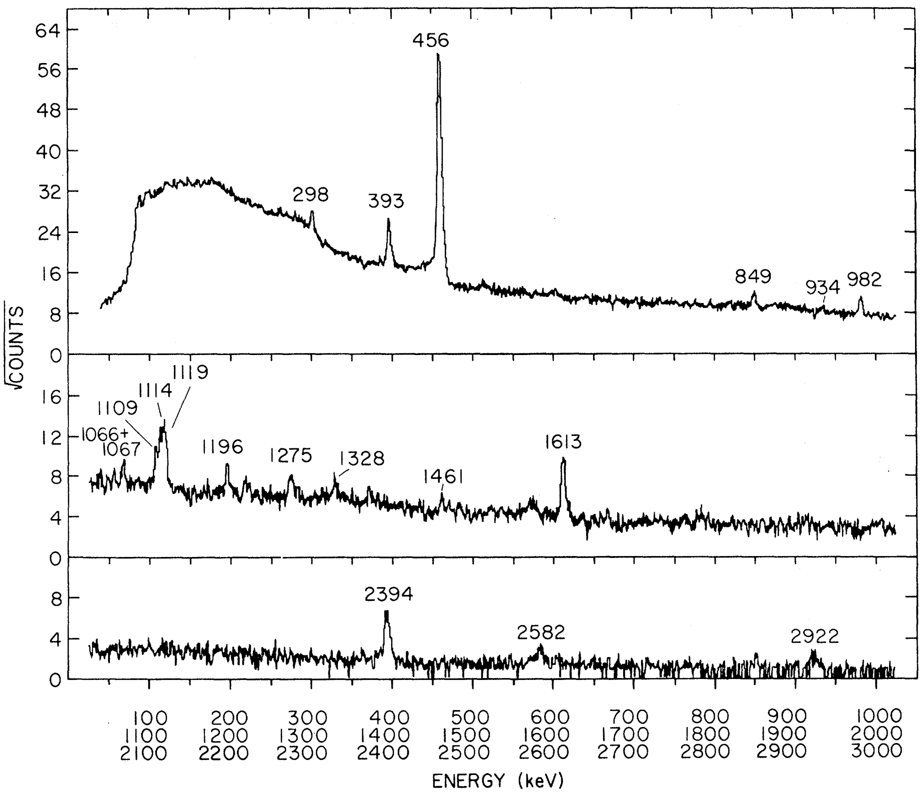

FIG. 3. Coincidence spectrum of the 456-keV gate.

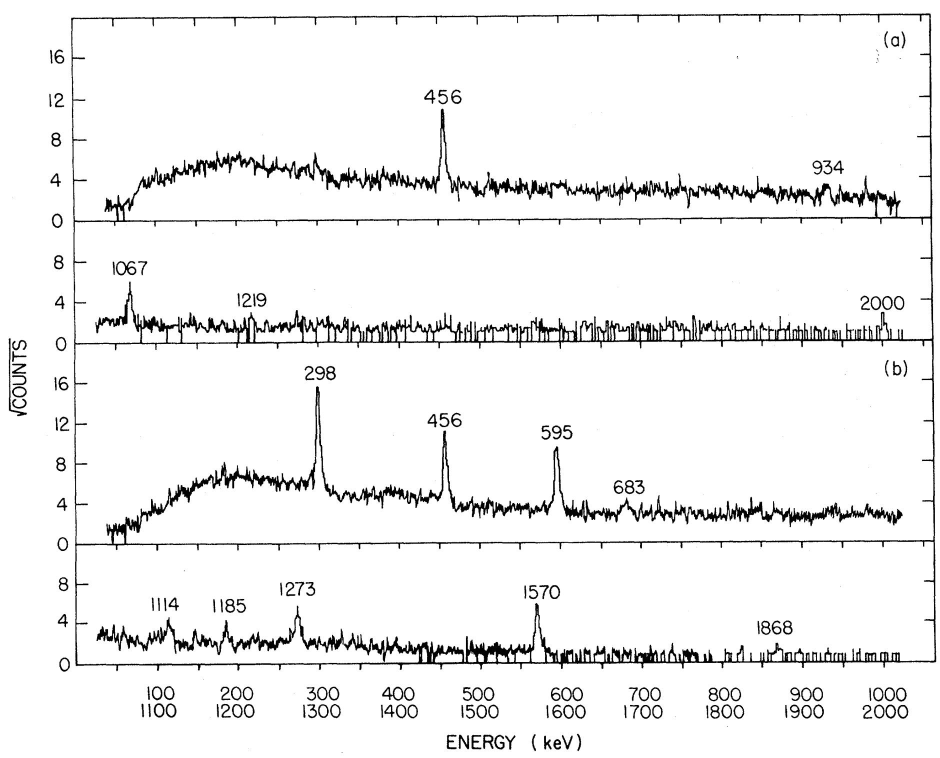

FIG. 4. Coincidence spectra for the gates at (a) 849 keV and (b) 982 keV.

TABLE II. $\gamma\gamma$ coincidences in the decay of ^{137}Xe.

Gating transition (keV)	Definite coincidences (keV)	Possible coincidences (keV)
298	982, 1114, 1570	456
393	456	1067
456	298, 393, 982, 1066, 1067, 1109, 1114, 1119, 1196, 1328, 1461, 1613, 2394, 2582, 2922	934, 3452
595	982, 1273	
683	982, 1185	
849	1067, 2000, 2188	934, 1219, 2096
934	849, 1067, 1461, 1916	456
982	298, 456, 595, 1114, 1185, 1273, 1570	683, 1868
1066	1328, 1783	456
1067	849, 934	393, 456
1114	298, 456, 982	
1119	456	2212
1185	683, 982, 1665	1102
1196		456
1273	595, 982, 1577	
1328	456, 1066	
1461	456, 934	
1570	298, 982	1280
1577		1273
1613	456	
1665	1185	
1783	1066	2003
1868	982	
1916	934	
2394		456

ceptance window of 60 nsec was used. The coincidence spectra were recorded on magnetic tape event by event in a buffered memory tape unit with 4096 by 4096 channel resolution. A total of 6×10^6 events was recorded in a period of 43 hours. A computer sorting routine was used to obtain the spectra in coincidence with selected peak and background gates. A comparison of the gated peak and background spectra was made visually to determine the appropriate coincidence relationships. The spectrum in coincidence with the strong 456-keV γ ray is shown in Fig. 3 and spectra in coincidence with γ rays at 849 and 982 keV are shown in parts (a) and (b), respectively, of Fig. 4. The spectra in Fig. 4 were important in determining the absence of a level at 982 keV. The results of all the coincidence measurements are summarized in Table II.

III. DECAY SCHEME AND DISCUSSION

The level scheme for the $N=82$ nucleus ^{137}Cs resulting from the decay study of ^{137}Xe is given in Fig. 5. β branching to the ^{137}Cs levels was determined using the proposed decay scheme and assuming $(67\pm3)\%$ β feeding to the ground state as determined by Onega and Pratt.[10] A Q_β of 4150 $\pm$ 100 keV obtained by Holm[2] was used in $\log ft$ calculations (we did not use the value adopted in the $A=137$ compilation due to uncertainty in the data used for the adopted value—see Ref. 6 for details). The results of these calculations are summarized in Table III. The ^{137}Cs ground-state spin has been measured by atomic-beam methods[6] to be $\frac{7}{2}$ and positive parity is preferred on shell-model grounds. A J^π of $\frac{7}{2}^-$ is preferred for the ^{137}Xe ground state on the basis of shell-model considerations and angular distributions from the ^{136}Xe$(d,p)^{137}$Xe reaction.[11] The above J^π is consistent with a $\log f_1 t$ (Ref. 12) of 8.2 for the β transition to the ^{137}Cs ground state. A discussion of some of the more interesting ^{137}Cs excited states follows.

455.51-keV level. This state is well established in earlier work.[2-5, 10] Single-proton transfer reactions[4] indicate this level to contain most of the $d_{5/2}$ single-particle strength, thus a J^π of $\frac{5}{2}^+$ is preferred. This assignment is consistent with a

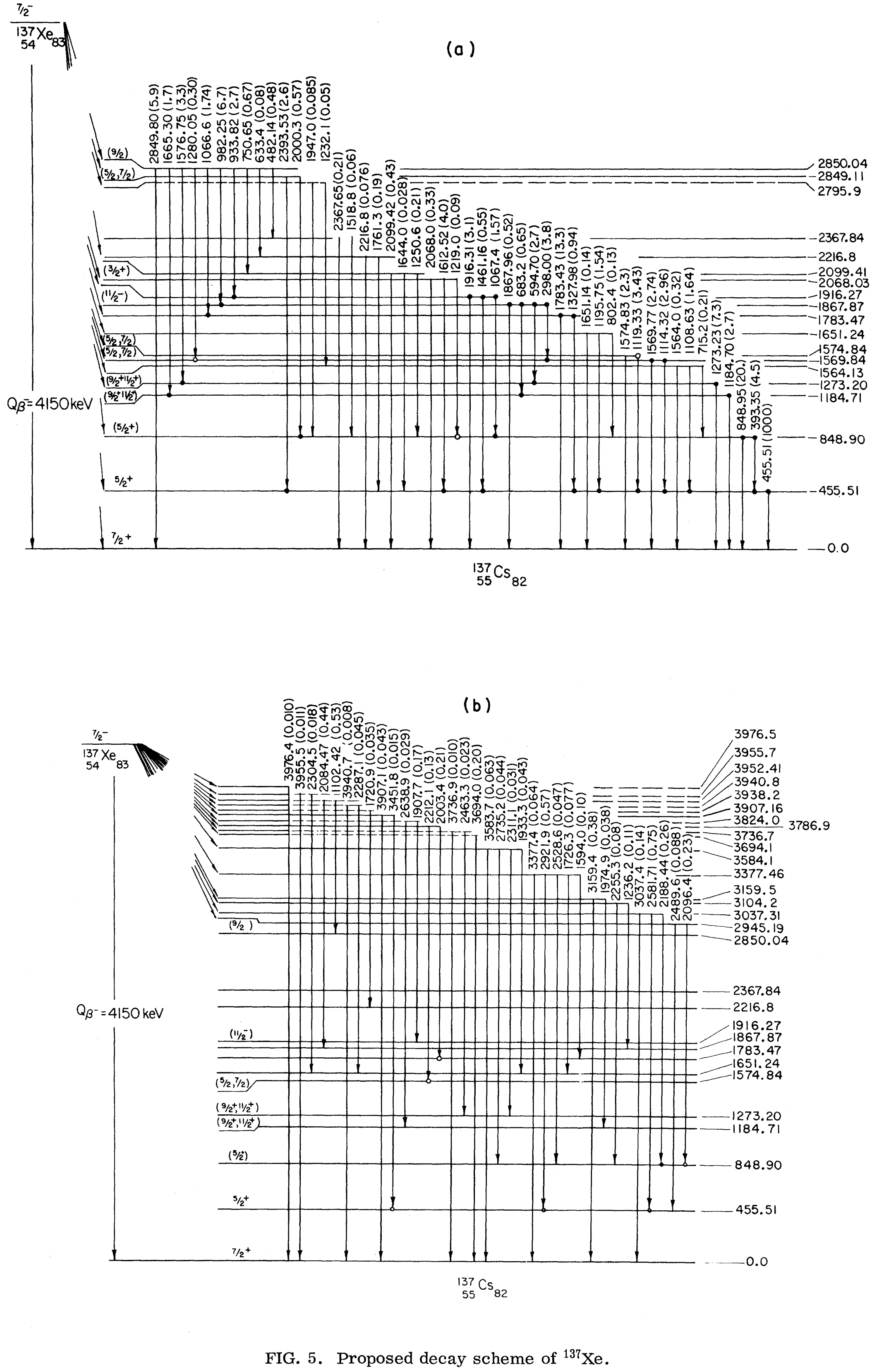

FIG. 5. Proposed decay scheme of ^{137}Xe.

TABLE III. β branching and $\log ft$ values for ^{137}Xe decay.

Level energy (keV)	β branching (%)	Logft
0	67.0[a]±3.0	6.6±0.1[b]
455.51±0.05	30.4±3.1	6.7±0.1[b]
848.90±0.06	0.65±0.08	8.2±0.1
1184.71±0.05	<0.02	>9.5
1273.20±0.06	0.04±0.03	9.1±0.3
1564.13±0.06	0.066±0.010	8.7±0.1
1569.84±0.06	0.050±0.014	8.8±0.1
1574.84±0.06	0.17±0.03	8.3±0.1
1651.24±0.08	0.051±0.007	8.8±0.1
1783.47±0.05	0.38±0.05	7.8±0.1
1867.87±0.07	<0.03	>8.8
1916.27±0.10	0.073±0.02	8.4±0.1
2068.03±0.07	0.14±0.02	8.0±0.1
2099.41±0.09	<0.003	>9.7
2216.8±0.2	0.005±0.002	9.3±0.2
2367.84±0.11	<0.003	>9.4
2795.9±0.2	0.004±0.001	8.8±0.1
2849.11±0.13	0.100±0.015	7.4±0.1[b]
2850.04±0.09	0.72±0.08	6.5±0.1[b]
2945.19±0.17	0.010±0.002	8.2±0.1
3037.31±0.09	0.036±0.005	7.5±0.1[b]
3104.2±0.3	0.006±0.001	8.2±0.1
3159.5±0.2	0.013±0.002	7.8±0.1[b]
3377.46±0.14	0.027±0.004	7.1±0.1[b]
3584.1±0.4	0.0056±0.0010	7.3±0.2[b]
3694.1±0.4	0.0062±0.0010	6.9±0.2[b]
3736.7±0.6	0.0010±0.0004	7.6±0.2[b]
3786.9±0.2	0.011±0.002	6.4±0.2[b]
3824.0±0.2	0.0061±0.0011	6.5±0.2[b]
3907.16±0.13	0.0018±0.0006	6.6±0.3[b]
3938.2±0.4	0.0025±0.0010	6.3±0.4[b]
3940.8±1.0	0.0002±0.0001	7.2±0.4[b]
3952.41±0.15	0.030±0.004	5.1±0.4[b]
3955.7±0.6	0.0009±0.0003	6.6±0.4[b]
3976.5±0.9	0.0003±0.0001	6.9±0.4[b]

[a]Measured value from Ref. 10.
[b]$\log f_1t < 8.5$ therefore first-forbidden unique β transition excluded.

β branching $\log f_1 t$ of 8.2 to the level.

848.90-keV level. This level was established in earlier decay[2,3] and μ^- capture studies.[5] Although the J^π is not known, recent shell-model calculations[7,8] postulate a $\frac{5}{2}^+$ level as the second-excited state. This suggests a possible $\frac{5}{2}^+$ assignment for this level.

A major point of departure of of our results from previous decay studies[2,3] is the absence of a level at 982 keV. We place the 982-keV γ ray between the 2850- and 1868-keV levels and find it coincidence with all γ rays depopulating the 1868-keV level. The most important point concerns observation of a 456-982-keV coincidence. A careful analysis of the 456-keV peak in the spectrum in coincidence with the 982-keV gate shows that 40% of the counts in the 456-keV peak are true coincidences which cannot be accounted for in terms of either accidentals or coincidences with Compton events from higher energy γ rays. Another consideration is the fact that the 456- as well as the 982-keV γ rays are prominent in the spectrum in coincidence with the 1114-keV gate, but no 527-keV γ ray is observed. According to the decay scheme of Monnand *et al.*[3] the 456- and 527-keV γ rays would be seen at about equal intensity, but the 982-keV γ ray would be much stronger.

The other major discrepancy exists between this work and that of Monnand *et al.*[3] in the ordering of four cascades from the 2850-keV level to the ground state. We postulate levels at 1185, 1273, 1570, and 1868 keV rather than 1665, 1577, 1280, and 982 keV, respectively. This choice results from the elimination of the 982-keV level and is supported by extensive coincidence measurements and reasonable intensity balances for the levels involved.

1184.71- and 1273.20-keV levels. Both of these levels are weakly fed in β decay and deexcite to only the $\frac{7}{2}^+$ ground state. This γ branching implies a spin assignment greater than $\frac{5}{2}$. Shell-model calculations[7,8] predict a doublet with J^π values of $\frac{11}{2}^+$ and $\frac{9}{2}^+$ just above 1 MeV which may correspond to these levels.

A number of levels were observed between 1.2 and 2.8 MeV. The $\log f_1 t$ values for all these levels are greater than 8.5; therefore, only weak arguments based on γ branching could be used to limit the possible J^π assignments.

1569.84- and 1574.84-keV levels. These levels populated the $\frac{7}{2}^+$ ground state and $\frac{5}{2}^+$ first-excited states with comparable intensities. We thus favor spins of $\frac{5}{2}$ or $\frac{7}{2}$.

1867.87-keV level. The β feeding to this level is zero within our limit of error. Depopulation occurs to the $g_{7/2}$ ground state but not to the $d_{5/2}$ first-excited state nor to the ($\frac{5}{2}^+$) level at 849 keV. This level could thus correspond to the $h_{11/2}$ single-proton state observed in transfer reactions.[4]

2068.03-keV level. This level deexcites strongly to the $d_{5/2}$ state at 456 keV but only weakly to the $g_{7/2}$ ground state. It is therefore attractive to associate this level with the $d_{3/2}$ single-proton state observed in transfer reactions.[4]

It was not possible to significantly restrict the J^π values for other levels between 1.3 and 2.8 MeV.

2849.11- and 2850.04-keV levels. In contrast to the singlet at 2850.0 reported by Monnand *et al.*[3] we postulate a doublet of levels at about 2850 keV, based on the lower values for the 2393.53+455.51- and 2000.3+848.95-keV γ-ray sums. Both levels have β branching $\log f_1 t$ values < 8.5 which limits

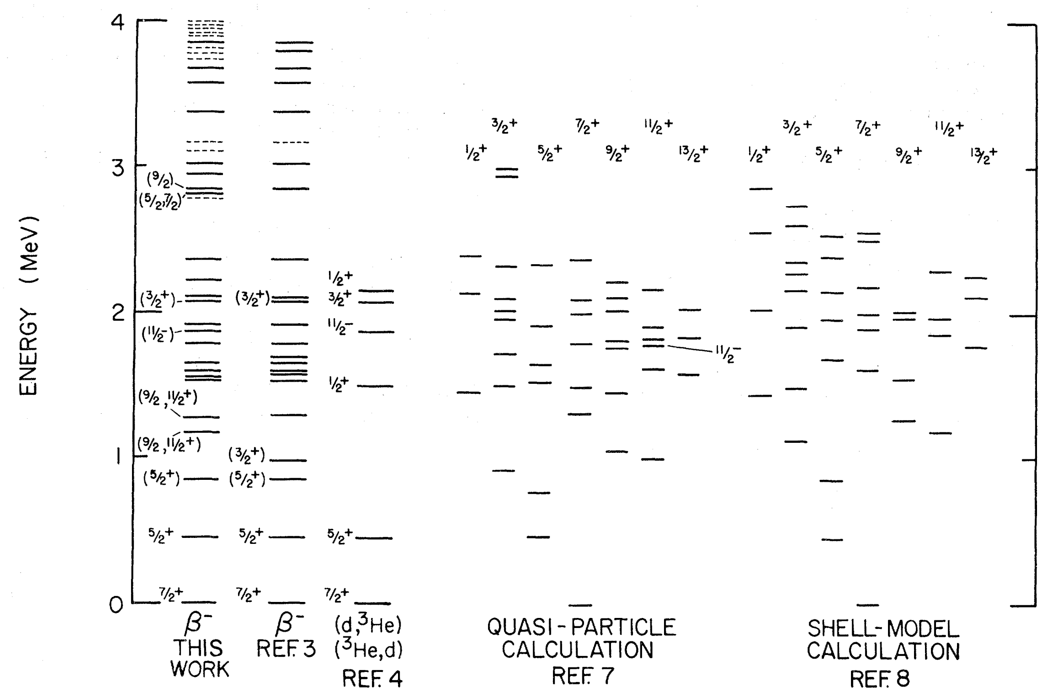

FIG. 6. Comparison of our levels in ^{137}Cs with previous experiments and shell-model calculations.

their spins to $\frac{5}{2}$, $\frac{7}{2}$, or $\frac{9}{2}$. Based on the deexcitation patterns to lower levels, we prefer a spin of $\frac{5}{2}$ or $\frac{7}{2}$ for the 2849-keV level and $\frac{9}{2}$ for the 2850-keV level. The level at 2850 keV is unusual in that it is populated by 36% of the ^{137}Xe β feeding to levels about 1.0 MeV. A similar phenomenon has been noted in the $N=82$ isotone ^{136}Xe where a level at 4269 keV, which was strongly fed in the β decay of ^{136}I,[13] was identified as a neutron particle-hole state in proton inelastic scattering experiments.[14] The 2850-keV level could possibly be interpreted as a neutron particle-hole state coupled to the $g_{7/2}$ proton. Another possible interpretation would be that it is a three quasiparticle state with one of the particles $h_{11/2}$.

All levels above 3.0 MeV, with the exception of the 3104-keV state, have β branching $\log f_1 t$ values less then 8.5. This limits the spins of these levels to $\frac{5}{2}$, $\frac{7}{2}$, or $\frac{9}{2}$ if we assume a $\frac{7}{2}^-$ J^π for the ^{137}Xe ground state.

The ^{137}Cs level scheme reported in this work is compared in Fig. 6 with results from the ^{137}Xe decay study of Monnand *et al.*[3] and from single-proton transfer reactions.[4] The extensive coincidence measurements carried out in our experiment enabled us to construct a decay scheme significantly different from earlier results.[2,3] Single-proton transfer reactions[4] have shown that most of the $g_{7/2}$, $d_{5/2}$, $h_{11/2}$, and $d_{3/2}$ single-proton strength is concentrated in levels in ^{137}Cs at 0, 0.455, 1.87, and 2.07 MeV, respectively, which probably correspond to levels observed at 0, 456, 1868, and 2068 keV in our experiment. We did not observe the $s_{1/2}$ state since a directly populating β transition from the $\frac{7}{2}^-$ ^{137}Xe ground state would be third forbidden and low-spin states above 2.15 MeV (the location for the $s_{1/2}$ state reported in Ref. 4) which could be fed by β decay and cascade into this state are not strongly populated.

Our results are also compared in Fig. 6 with the quasiparticle calculation of Heyde and Waroquier[7] and the shell-model calculation of Wildenthal.[8] Below 1.3 MeV the results of the two calculations are similar. The results from our experiment, assuming the 1185- and 1273-keV levels to be $\frac{11}{2}^+$ and $\frac{9}{2}^+$, respectively, are in slightly better agreement with the results of Wildenthal.[8] We do not observe a $\frac{3}{2}^+$ level predicted[7,8] to occur at about 1.0 MeV. Such a level would presumably be fed by a weak first-forbidden unique β transition and could well be missed in our experiment. Unfortunately J^π information on levels above 1.5 MeV is rather meager; therefore, a detailed comparison with the shell-model calculations is not yet possible.

*Present address: Bettis Atomic Power Laboratory, Westinghouse Electric Corporation, West Mifflin, Pennsylvania 15122.

†Prepared for the U. S. Energy Research and Development Administration under Contract No. W-7405-eng-82.

[1]W. Seelmarn-Eggebert and H. J. Born, Naturwiss, 31, 59 (1943).

[2]G. Holm, Ark. Fys. 37, 1 (1968).

[3]E. Monnand, R. Brissot, J. Crancon, Ch. Ristori, F. Schussler, and A. Moussa, J. Phys. Rad. 36, 1 (1975).

[4]B. H. Wildenthal, E. Newman, and R. L. Auble, Phys. Rev. C 3, 1199 (1971).

[5]G. R. Lucas, Jr., P. Martin, G. H. Miller, R. E. Welsh, D. A. Jenkins, R. J. Powers, and A. R. Kunselman, Phys. Rev. C 7, 1678 (1973).

[6]R. L. Bunting, Nucl. Data Sheets 15, 335 (1975).

[7]K. Heyde and M. Waroquier, Nucl. Phys. A167, 545 (1971).

[8]B. H. Wildenthal, private communication to K. Heyde and M. Waroquier.

[9]J. R. McConnell and W. L. Talbert, Jr., Nucl. Instrum. Methods 128, 227 (1975).

[10]R. J. Onega and W. W. Pratt, Phys. Rev. 136, B365 (1964).

[11]P. A. Moore, P. J. Riley, C. M. Jones, M. D. Mancusi, and J. L. Foster, Jr., Phys. Rev. 175, 1516 (1968).

[12]S. Raman and N. B. Gove, Phys. Rev. C 7, 1995 (1973).

[13]W. R. Western, John C. Hill, W. L. Talbert, Jr., and W. C. Schick, Jr., Phys. Rev. C (to be published).

[14]P. A. Moore, P. J. Riley, C. M. Jones, M. D. Mancusi, and J. L. Foster, Jr., Phys. Rev. C 1, 1100 (1970).