PHYSICAL REVIEW C VOLUME 9, NUMBER 1 JANUARY 1974

Angular-correlation and branching-ratio studies of ^{41}Ca with the ^{40}Ca($d, p\gamma$)^{41}Ca reaction*

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(Received 6 August 1973)

Collinear-geometry angular-correlation and branching-ratio information is presented on 28 levels in ^{41}Ca up to approximately 4.5 MeV excitation. The ^{40}Ca($d,p\gamma$)^{41}Ca reaction was used with an incident deuteron energy of 3 MeV. γ rays were detected with a Ge(Li) detector.

[NUCLEAR REACTIONS ^{40}Ca($d,p\gamma$), E = 3 MeV; measured p-γ angular correlations, branching ratios; deduced δ. Ge(Li) detector.]

I. INTRODUCTION

In a recent experiment[1] utilizing the ^{40}Ca($d, p\gamma$)-^{41}Ca reaction we presented particle-γ angular-correlation and electromagnetic branching-ratio information on several levels near 3614 keV excitation in ^{41}Ca. That work was limited in scope and the collinear geometry angular-correlation information was obtained from measurements at $\theta_\gamma = 0°$ and $\theta_\gamma = 90°$ only. In the present experiment we have extended this investigation to include all levels up to approximately 4.5 MeV excitation and have obtained angular-correlation data on many of these levels at five angles between 0 and 90°.

The study of ^{41}Ca with stripping and pickup reactions has been quite extensive. One of the earliest and most comprehensive is the ^{40}Ca(d, p)-^{41}Ca experiment by Belote, Sperduto, and Buechner.[2] Although several other (d, p) studies have since been published, they have identified no levels not seen in Ref. 2. Other reactions employed in experiments which involve more than a few strong levels include the ^{39}K(^{3}He, p)^{41}Ca reaction,[3,4] the ^{42}Ca(^{3}He, α)^{41}Ca reaction,[5] the ^{42}Ca-(p, d)^{41}Ca reaction,[6] the ^{40}Ca(α, ^{3}He)^{41}Ca reaction,[7] and the ^{42}Ca(d, t)^{41}Ca reaction.[8] Experiments involving electromagnetic decay of ^{41}Ca levels have utilized the ^{40}Ca(n, γ)^{41}Ca reaction,[9,10] the ^{41}K-($p, n\gamma$)^{41}Ca reaction,[11] the ^{40}Ca($d, p\gamma$)^{41}Ca reaction,[1,12-17] and the ^{39}K(^{3}He, $p\gamma$)^{41}Ca reaction.[4]

The energy spectrum and level properties of ^{41}Ca are of particular interest since the simple closed-shell-plus-neutron model has been shown to be quite inadequate to account for the experimental facts. More sophisticated theories involving deformed states seem to be necessary.[18]

II. EXPERIMENTAL

The ^{40}Ca($d, p\gamma$)^{41}Ca reaction was used with an incident deuteron energy of 3 MeV. Self-supporting natural calcium targets about 1 mg/cm^2 in areal density were used. Protons were detected in a 300-mm^2-area, 1000-μm-thick Si annular detector 2 cm from the target covering angles θ = 153–174° relative to the beam direction. The detector was covered with 50 μm of Al to stop elastically scattered deuterons.

γ rays were detected with a ~40-cm^3 Ge(Li) detector 4 cm from the target at angles of 0, 30, 45, 60, and 90° relative to the beam. Beam currents were typically 2–4 nA and runs were on the order of 12–15-h duration at each angle. Small beam currents were necessary to maintain good resolution in the γ-ray detection system which was adversely affected by high count rates. Normalization of the runs at various angles was done by scaling the ground-state proton group in the annular detector.

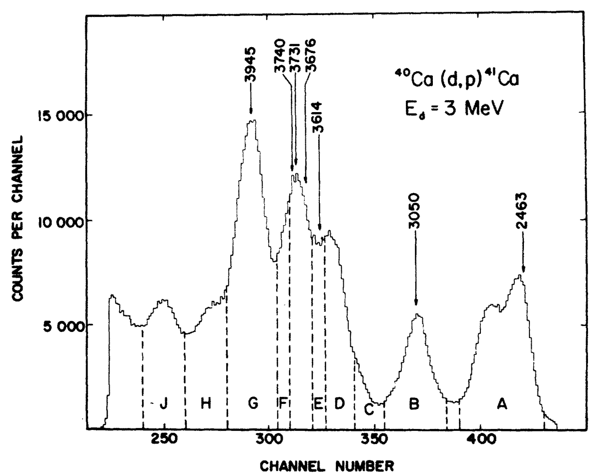

FIG. 1. Partial spectrum of protons in the annular Si detector coincident with all γ rays. This particular spectrum has the 1943- and 2010-keV levels biased out and only a few excitation energies are shown for orientation. The energy windows used to generate the γ-ray spectra in Figs. 3–7 are shown.

TABLE I. Angular-correlation and branching-ratio results.

Level No.	Transition	E_γ	Branching ratio	Branching ratio (Previous work)	A_2/A_0	$J_i \to J_f$	Mixing ratio
1	1943→0	1943	100	100 [a,b]	0.10 ± 0.03	$\frac{3}{2}\to\frac{7}{2}$	No restriction
2	2010→0	2010	100	100 [a,b]	0.02 ± 0.04	$\frac{3}{2}\to\frac{7}{2}$	No restriction
3	2463→1943	520	100	100 [a,b]	0.27 ± 0.01	$\frac{3}{2}\to\frac{3}{2}$	$-5.7<x<0.18$ $0.47<x<5.7$
4	2578→0	2578	100	100 [a,b]	0.35 ± 0.04	$\frac{3}{2}\to\frac{7}{2}$	$-\infty<x<-0.38$ $0.18<x<1.04$ $4.33<x<\infty$
						$\frac{5}{2}\to\frac{7}{2}$	$0.31<x<2.14$
						$\frac{7}{2}\to\frac{7}{2}$	$-1.73<x<0.23$
						$\frac{9}{2}\to\frac{7}{2}$	$-8.14<x<-2.48$ $-0.58<x<-0.27$
						$\frac{11}{2}\to\frac{7}{2}$	$-\infty<x<-5.67$ $-0.12<x<0.18$ $11.4<x<\infty$
5	2605→0	2605	100	100 [a,b]	−0.19 ± 0.04	$\frac{3}{2}\to\frac{7}{2}$	$-\infty<x<-0.18$ $-0.09<x<1.73$ $2.14<x<\infty$
						$\frac{5}{2}\to\frac{7}{2}$	$-\infty<x<0.09$ $4.33<x<\infty$
						$\frac{7}{2}\to\frac{7}{2}$	$-\infty<x<-3.73$ $0.58<x<\infty$
						$\frac{9}{2}\to\frac{7}{2}$	$-0.14<x<0.09$ $3.73<x<\infty$
						$\frac{11}{2}\to\frac{7}{2}$	$0.47<x<2.75$
6	2670→1943	727	71 ± 3	73 ± 4 [a] 70 [b] 65 [c]	−0.03 ± 0.04	$\frac{1}{2}\to\frac{3}{2}$	
	2670→2010	660	29 ± 2	27 ± 4 [a] 30 [b] 35 [c]	−0.03 ± 0.04	$\frac{1}{2}\to\frac{3}{2}$	
7	2882→0	2882	100	100 [a,b]	0.19 ± 0.09	$\frac{3}{2}\to\frac{7}{2}$	No restriction
					(0.21 ± 0.08) [b]	$\frac{5}{2}\to\frac{7}{2}$	$-\infty<x<-5.67$ $-0.27<x<\infty$
						$\frac{7}{2}\to\frac{7}{2}$	$-\infty<x<0.84$
						$\frac{9}{2}\to\frac{7}{2}$	$-\infty<x<-1.73$ $-0.90<x<-0.18$ $5.67<x<\infty$
						$\frac{11}{2}\to\frac{7}{2}$	$-\infty<x<-2.75$ $-0.27<x<0.75$ $1.54<x<\infty$
8	2960→0	2960	100	100 [a,b]	0.11 ± 0.06	$\frac{3}{2}\to\frac{7}{2}$	No restriction
					(0.29 ± 0.03) [b]	$\frac{5}{2}\to\frac{7}{2}$	$-\infty<x<-7.12$ $-0.27<x<\infty$
						$\frac{7}{2}\to\frac{7}{2}$	$-\infty<x<0.84$
						$\frac{9}{2}\to\frac{7}{2}$	$-\infty<x<-3.73$ $-0.49<x<-0.09$ $11.4<x<\infty$
						$\frac{11}{2}\to\frac{7}{2}$	$-\infty<x<-8.14$ $-0.03<x<\infty$

TABLE I *(Continued)*

Level No.	Transition	E_γ	Branching ratio	Branching ratio (Previous work)	A_2/A_0	$J_i \rightarrow J_f$	Mixing ratio
9	3050→0	3050	···	2±1 [a]	···	···	
				≤10 [b]			
	3050→1943	1107	21±2	18±4 [a]	0.14±0.07	$\frac{3}{2}\rightarrow\frac{3}{2}$	No restriction
						$\frac{5}{2}\rightarrow\frac{3}{2}$	$-\infty<x<0.11$
				35 [b,d]			$2.61<x<\infty$
	3050→2010	1040	37±3	42±6 [a]	−0.03±0.04	$\frac{3}{2}\rightarrow\frac{3}{2}$	No restriction
					(−0.00±0.03) [b]	$\frac{5}{2}\rightarrow\frac{3}{2}$	$-\infty<x<-3.73$
							$-0.58<x<0.27$
							$1.73<x<\infty$
	3050→2605	445	38±3	38±6 [a]	−0.04±0.03	···	
				55 [b]			
	3050→2670	380	4±2	···	−0.24±0.24	···	
10	3200→0	3200	100	100 [a,b]	−0.20±0.07	$\frac{3}{2}\rightarrow\frac{7}{2}$	No restriction
					(−0.25±0.03) [b]	$\frac{5}{2}\rightarrow\frac{7}{2}$	No restriction
						$\frac{7}{2}\rightarrow\frac{7}{2}$	$-\infty<x<-1.96$
							$0.27<x<\infty$
						$\frac{9}{2}\rightarrow\frac{7}{2}$	$-\infty<x<-11.4$
							$-0.27<x<0.18$
							$2.75<x<\infty$
						$\frac{11}{2}\rightarrow\frac{7}{2}$	$0.27<x<5.67$
11	3369→0	3369	···	39±8 [a]	···		
				20 [b]			
				45 [e]			
	3369→3200	169	···	61±8 [a]	···		
				80 [b]			
				55 [e]			
12	3400→2010	1390	100	100 [a,b]	0.10±0.07	$\frac{1}{2}\rightarrow\frac{3}{2}$	
				≥85 [e]			
13	3495→0	3495	5±2	≤10 [e]	···		
	3495→2010	1485	83±6	100 [a]	0.06±0.06	$\frac{3}{2}\rightarrow\frac{3}{2}$	No restriction
				≥76 [e]		$\frac{5}{2}\rightarrow\frac{3}{2}$	$-\infty<x<0.23$
							$1.73<x<\infty$
						$\frac{7}{2}\rightarrow\frac{3}{2}$	$-0.03<x<\infty$
	3495→3050	445	12±3	···	···		
14	3526→1943	1583	59±9	≥70 [e]	0.12±0.11	$\frac{3}{2}\rightarrow\frac{7}{2}$	No restriction
						$\frac{5}{2}\rightarrow\frac{7}{2}$	No restriction
						$\frac{7}{2}\rightarrow\frac{7}{2}$	No restriction
	3526→2010	1516	31±5	···	···		
	3526→2670	856	10±3	···	···		
15 [f]	3614→0	3614	26±6	20±6 [a]	0.31±0.09	$\frac{3}{2}\rightarrow\frac{7}{2}$	No restriction
				25 [b]	(0.26±0.04) [b]	$\frac{5}{2}\rightarrow\frac{7}{2}$	$0<x<7.12$
				28 [e]	(0.33±0.06) [g]	$\frac{7}{2}\rightarrow\frac{7}{2}$	$-4.70<x<0.58$
				45 [g]		$\frac{9}{2}\rightarrow\frac{7}{2}$	$-\infty<x<-0.12$
							$19.1<x<\infty$
	3614→1943	1671	31±6	40±5 [a]	−0.16±0.10	$\frac{3}{2}\rightarrow\frac{3}{2}$	No restriction
				44 [b,d]	(0.02±0.11) [g]	$\frac{5}{2}\rightarrow\frac{3}{2}$	$-\infty<x<-2.75$
				40 [c]			$-0.70<x<\infty$
				41 [e]		$\frac{7}{2}\rightarrow\frac{3}{2}$	$0.18<x<3.73$
				28 [g]			

TABLE I *(Continued)*

Level No.	Transition	E_γ	Branching ratio	Branching ratio (Previous work)	A_2/A_0	$J_i \to J_f$	Mixing ratio
	3614→2463	1151	30±7	28±3 [a]	···		
				31 [b]	(0.15±0.20) [g]		
				35 [c]			
				22 [e]			
				18 [g]			
	3614→2670	944	13±4	12±3 [a]	−0.05±0.16	$\frac{3}{2}\to\frac{1}{2}$	No restriction
				25 [c]	(0.01±0.21) [g]	$\frac{5}{2}\to\frac{1}{2}$	No restriction
				8 [e]		$\frac{7}{2}\to\frac{1}{2}$	No restriction
				9 [g]			
16	3676→0	3676	100	100 [e,g]	−0.44±0.08	$\frac{3}{2}\to\frac{7}{2}$	$-\infty<x<-0.36$
					(−0.67±0.10) [g]		$0.09<x<1.19$
							$4.01<x<\infty$
						$\frac{5}{2}\to\frac{7}{2}$	$-\infty<x<-0.03$
							$11.4<x<\infty$
						$\frac{7}{2}\to\frac{7}{2}$	$-\infty<x<-28.6$
							$0.84<x<\infty$
						$\frac{9}{2}\to\frac{7}{2}$	$-0.03<x<0.31$
							$1.96<x<7.12$
						$\frac{11}{2}\to\frac{7}{2}$	Not allowed
17a	3731→0	3731	24±4	27 [g]	0.05±0.08	$\frac{3}{2}\to\frac{7}{2}$	No restriction
						$\frac{5}{2}\to\frac{7}{2}$	No restriction
						$\frac{7}{2}\to\frac{7}{2}$	No restriction
						$\frac{9}{2}\to\frac{7}{2}$	$-\infty<x<-3.08$
							$-0.49<x<0.03$
							$5.67<x<\infty$
						$\frac{11}{2}\to\frac{7}{2}$	$-\infty<x<-7.12$
							$-0.05<x<\infty$
	3731→1943	1788	17±4	10 [g]	···		
	3731→2463	1268	35±6	38 [g]	0.06±0.10	$\frac{3}{2}\to\frac{3}{2}$	No restriction
						$\frac{5}{2}\to\frac{3}{2}$	No restriction
						$\frac{7}{2}\to\frac{3}{2}$	$-\infty<x<-3.73$
							$-0.40<x<\infty$
	3731→2578	1153	24±7	25 [g]	···		
17b	3740→2010	1730	67±7	59 [g]	−0.05±0.14	$\frac{3}{2}\to\frac{3}{2}$	No restriction
				60 [h]		$\frac{5}{2}\to\frac{3}{2}$	No restriction
						$\frac{7}{2}\to\frac{3}{2}$	$-\infty<x<-2.36$
							$-0.53<x<\infty$
	3740→2605	1135	33±4	41 [g]	···		
				40 [h]			
19	3845→1943	1902	22±13	100 [e,d]			
	3845→2010	1835	78±34				
21	3945→1943	2002	95±9	92±7 [a]			
				95 [c]			
				100 [e]			
	3945→2463	1482	5±1	6±2 [a]			
				5 [c]			
	3945→2670	1275	···	2±1 [a]			

TABLE I *(Continued)*

Level No.	Transition	E_γ	Branching ratio	Branching ratio (Previous work)	A_2/A_0	$J_i \rightarrow J_f$	Mixing ratio
22	3970→0	3970	55±10	34 [e]			
	3970→1943	2027	...	27 [e,d]			
	3970→2010	1960	...				
	3970→2460	1510	...	39 [e]			
	3970→2605	1365	45±10	...			
24	4090→0	4090	30±5	40±10 [a] 34 [h]			
	4090→2010	2080	70±10	60±10 [a] 58 [h]			
	4090→2605	1485	...	8 [h]			
25	4185→2010	2175	64±10	64±12 [a] 70 [h]			
	4185→2605	1580	36±5	36±12 [a] 30 [h]			
...	4275→0	4275	100	82±10 [a]			
	4275→2605	1670	...	18±10 [a]			

[a] Reference 16.
[b] Reference 15.
[c] Reference 9.
[d] This is the combined decay to the 1943- and 2010-keV levels.
[e] Reference 17.
[f] The results on level 15 are given as if only one level is present. See text and Ref. 1 for discussion of the possibility of two levels near this energy.
[g] Reference 1.
[h] Reference 4.

Two-dimensional pulse-height analysis was used and coincident events were stored on magnetic tape. Energy windows were then set on the proton spectrum and spectra of γ rays coincident with particular energy regions in the proton spectrum were generated. A spectrum of protons in coincidence with all γ rays is shown in Fig. 1 indicating some of the energy windows used.

III. RESULTS

The angular-correlation data were analyzed using the method of Litherland and Ferguson.[19] The equations of Poletti and Warburton[20] were used to calculate curves of χ^2 vs arctan$x$ for various spin choices for the levels concerned in each particular transition. In each case the angular-correlation data at five angles were fitted with two Legendre polynomials utilizing coefficients A_0 and A_2. In none of the cases considered was it possible to determine uniquely the spin of a level; however, in many cases restrictions on the mixing ratio for particular spin choices were obtained. Branching ratios were obtained both from the angular-correlation data and from a special run taken at $\theta_\gamma = 54°$. The results are presented in Table I. Possible values of the mixing ratio x were determined by the usual 0.1% confidence limit criterion which was in this case a χ^2 of 5.4 or less. Figure 2 is an energy-level diagram containing the branching-ratio results of the present experiment. The numbering of the levels is that of Belote, Sperduto, and Buechner.[2]

Figures 3–7 show spectra of γ rays in coincidence with the proton windows indicated in Fig. 2. The windows used for the spectra shown here are not necessarily those used in the angular correlations but were chosen to best illustrate the decay modes of the various levels. In particular, windows E and F were chosen to distinguish decay modes of the 3614-, 3676-, 3731-, and 3740-keV levels.

Following are comments on individual levels:

1943-, 2010-, and 2463-keV levels

These levels have known spins. The 1943- and 2463-keV levels are $J^\pi = \frac{3}{2}^-$ and contain the entire single-particle $p_{3/2}$ strength.[12] The 2010-keV level is $J^\pi = \frac{3}{2}^+$ and is assumed to be a $d_{3/2}$-hole state. The angular-correlation results produced no restrictions on the mixing ratio in the 1943- and

2010-keV level decays and only a small restriction in the 2463-keV decay.

2578- and 2605-keV levels

These levels both decay exclusively to the ground state. They are relatively weakly excited in the (d,p) reaction and were not assigned l_n values by Belote, Sperduto, and Buechner.[2] The 2578-keV level was given a tentative $l=(3)$ and $J^\pi=(\frac{7}{2}^-)$ identification in the ^{42}Ca(^{3}He, α)^{41}Ca reaction.[5] The 2605-keV level was assigned $l=3$ and $J^\pi=\frac{7}{2}^-$ in the same experiment. The above $J^\pi=\frac{7}{2}^-$ proposals as well as that of Johnson *et al.*[15] who proposed identification of the 2578-keV level with a calculated $J^\pi=\frac{5}{2}^-$ level are based on rough identification with calculated levels and not on direct experimental evidence.

The angular-correlation results presented here do not contribute to a more definite spin assignment but do provide some restrictions on possible mixing ratios.

2670-keV level

This state is observed with $l_n=0$ in the (d,p) reaction,[2] the (p,d) reaction,[6] the (^{3}He, α) reaction,[5] and the (d,t) reaction.[8] It consequently has been assigned $J^\pi=\frac{1}{2}^+$ and is assumed to correspond to a $s_{1/2}$-hole state. The isotropic angular correlations reported here are consistent with the $J^\pi=\frac{1}{2}^+$ assignment and the branching ratio is in agreement with previous results.[9,15,16]

2882-, 2960-, 3050-, and 3200-keV levels

None of these four levels was assigned l_n values in the (d,p) reaction by Belote, Sperduto, and Buechner.[2] The 2882-keV level is observed with a tentative $l=(4)$ in the (α, ^{3}He) reaction,[7] and $L=2$ in the (^{3}He, p) reaction.[3] Johnson *et al.*[15] suggest $J^\pi=(\frac{7}{2}^+)$ for this level. The 2960-keV level is observed with $l_n=3$ in the (p,d)[6] and (^{3}He, α)[5] pickup reactions and is assigned $J^\pi=\frac{7}{2}^-$ by them on the basis of excitation energy together with the fact that the higher excitation $l=3$ transitions at 4.894 and 5.686 MeV in the (d,p) reaction[2] are ascribed to $f_{5/2}$ capture. The 3050-keV level has not been assigned l_n values by any capture or pickup reaction. Previous[15] angular-correlation data allow $J\leq\frac{5}{2}$. The present angular-correlation data allow $J\leq\frac{7}{2}$, however, the observed branch to the $\frac{1}{2}^+$ 2670-keV level argues against $J=\frac{7}{2}$. The 3200-keV level is observed with a tentative $l_n=(3)$ in the (^{3}He, α) reaction[5] and $l_n=3$ in the (α, ^{3}He) reaction.[7] Youngblood *et al.*[7] suggest $J^\pi=\frac{5}{2}^-$ for this level together with the 3174-keV mirror level in ^{41}Sc. However, Johnson *et al.*[15] and Cohen *et al.*[17] propose $J^\pi=\frac{9}{2}^+$ to explain the transition to this level from the 3369-keV level for which they propose $J\geq\frac{11}{2}$.

The 2882-, 2960-, and 3200-keV levels were observed to decay exclusively to the ground state in agreement with previous results. The reported[16] ground-state decay of the 3050-keV level was not observed in this experiment and a previously unreported weak branch to the 2670-keV level is

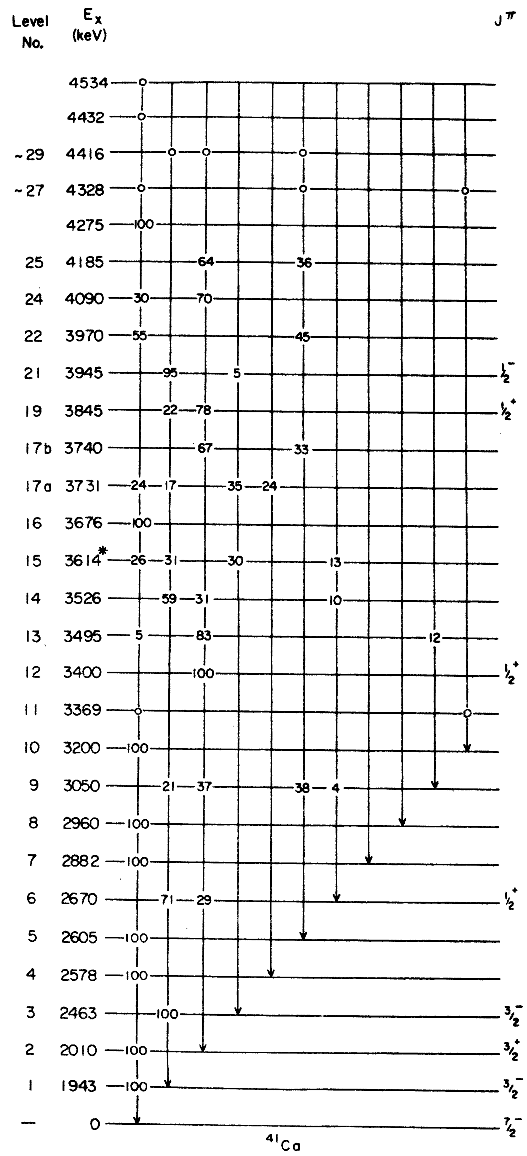

FIG. 2. Energy level diagram showing observed transitions and branching ratios. The circles indicate those cases where the transition was observed but a branching ratio was not obtained. The level numbers are those of Ref. 2. The 3614-keV level is treated as a single level in this figure.

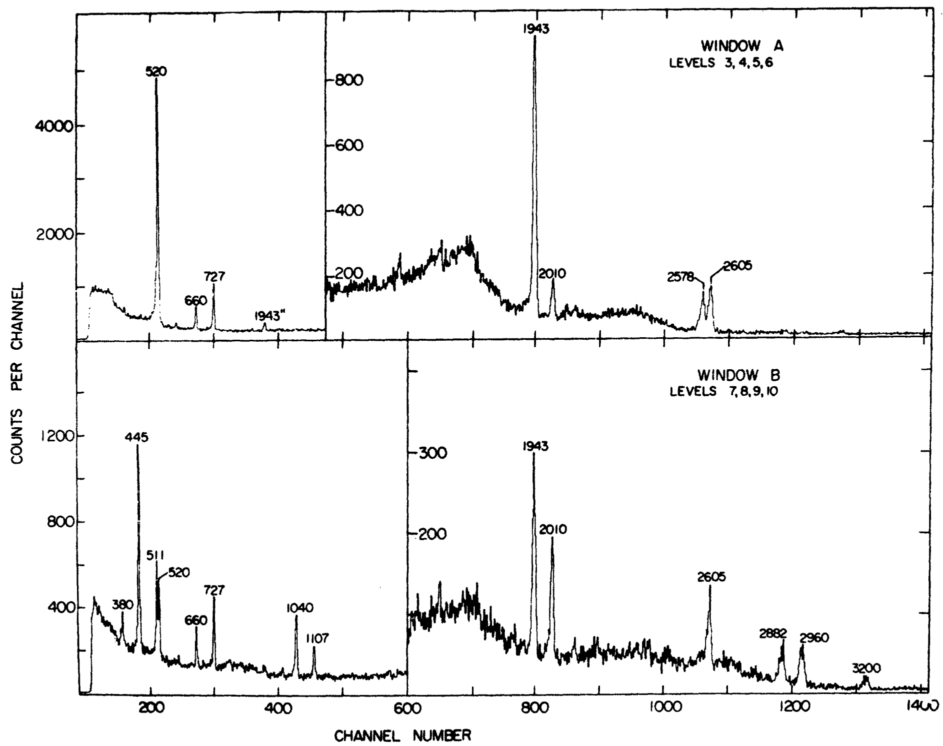

FIG. 3. Energy spectra of γ rays in coincidence with protons in windows A and B. γ-ray energies are given in keV and the levels whose decay is observed in these spectra are indicated on the figure. Single- and double-escape peaks are indicated by ′ and ″, respectively. The energy dispersion is 2.5 keV/channel and $\theta_{\gamma} = 90°$.

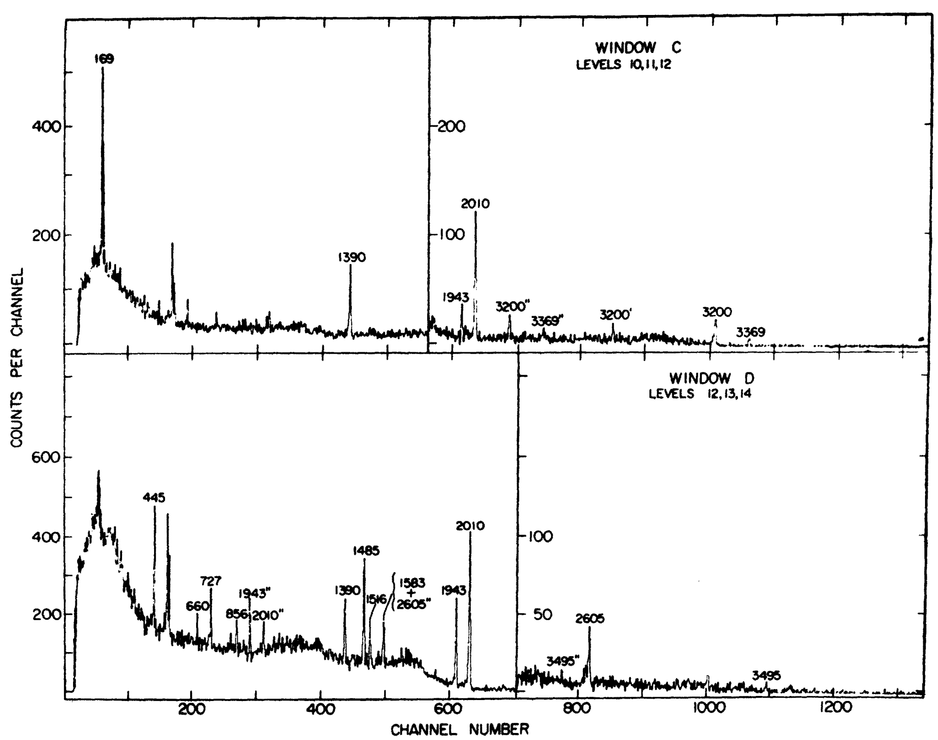

FIG. 4. Energy spectra of γ rays in coincidence with protons in windows C and D. The energy dispersion is 3.2 keV/channel. The notation is the same as in Fig. 3.

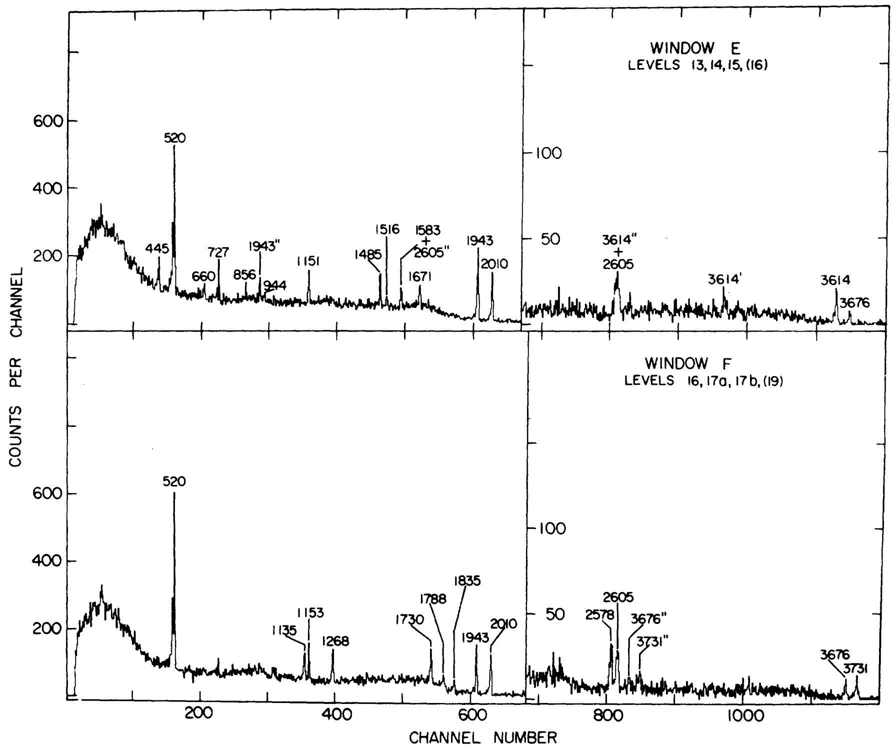

FIG. 5. Energy spectra of γ rays in coincidence with protons in windows E and F. Window E was chosen to include the 3614-keV level but exclude as much as possible higher states. Window F was chosen to exclude the 3614-keV state. The energy dispersion is 3.2 keV/channel. The notation is the same as in Fig. 3.

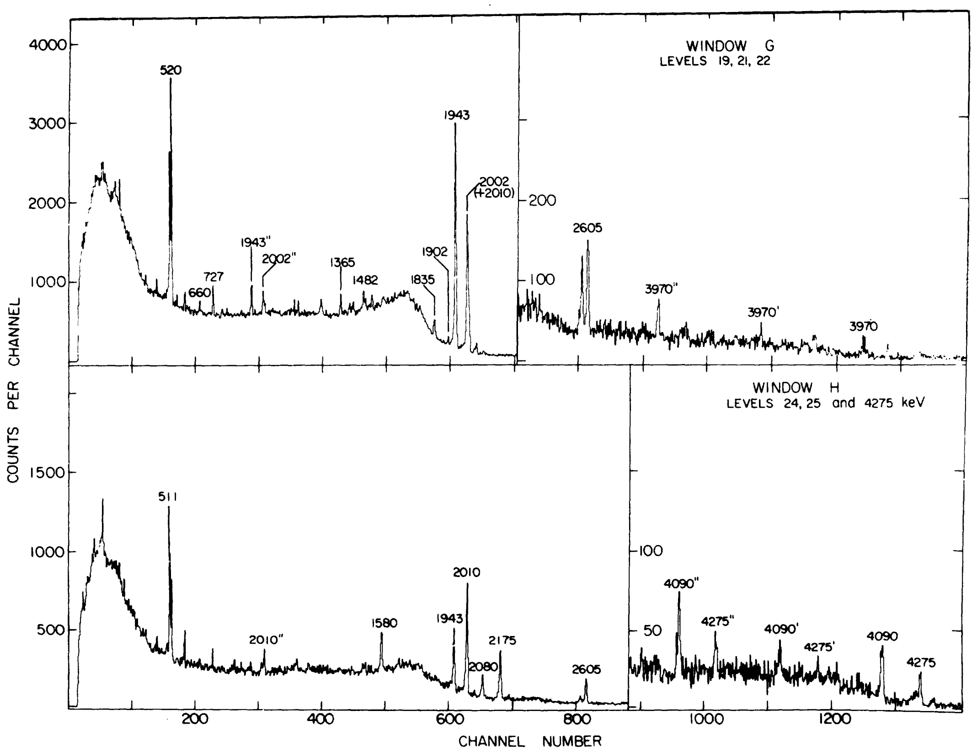

FIG. 6. Energy spectra of γ rays in coincidence with protons in windows G and H. The energy dispersion is 3.2 keV/channel. The notation is the same as in Fig. 3.

proposed (see Table I and Fig. 2). The angular correlations of these four levels are in good agreement with previous results[15] taken with NaI and a deuteron energy of 4.04 MeV except for the discrepancy in the A_2/A_0 for the 2960-keV level decay. Results and comparisons are shown in Table I.

3369-, 3400-, 3495-, and 3526-keV levels

No angular-correlation or branching-ratio information was obtained concerning the 3369-keV level. This level is discussed in Refs. 7 and 15.

The 3400-keV level is observed with $l_n = 0$ in the (d,p),[2] (p,d),[6] $(^3He, \alpha)$,[5] and (d,t)[8] reactions. It therefore has $J^\pi = \frac{1}{2}^+$. It also is seen in the $(^3He, p)$ reaction,[4] where a $[d_{3/2}{}^{-1}(\frac{3}{2}, \frac{1}{2}) f_{7/2}{}^2(1,0)]_{1/2}$ configuration is suggested. The isotropic angular correlation observed in the decay to the 2010-keV level is consistent with this picture.

The 3495-keV level is seen only weakly in the (d,p) reaction,[2] and is not reported in the other stripping and pickup reactions. Only the angular correlation of the decay to the 2010-keV level is reported here, although weak branches to the ground state and the 3050-keV level were seen.

The 3526-keV level is observed with $l_n = 3$ in the $(^3He, \alpha)$ reaction[5] and was assigned $J^\pi = \frac{7}{2}^-$. The (p,d)[6] and (d,t)[8] experiments, on the other hand, assign this level $l_n = 2$ and suggest $J = \frac{3}{2}$. Our angular-correlation results do not eliminate any spin choices, however the assignment $J^\pi = \frac{7}{2}^-$ seems unlikely in view of our observed branch to the $\frac{1}{2}^+$ 2670 level.

3614-, 3676-, 3731-, and 3740-keV levels

Angular-correlation and branching-ratio information on these four levels based on measurements at $\theta_\gamma = 0°$ and $\theta_\gamma = 90°$ have been previously presented.[1] We present here improved results from data taken at five angles.

The 3614-keV level is observed with $l_n = 1$ in the (d,p) reaction[2] and the $(\alpha, {}^3He)$ reaction.[7] This, together with measurements[1,13,15] of the anisotropic angular correlation from the decay of this state would seem to indicate $J^\pi = \frac{3}{2}^-$. A definite $J = \frac{1}{2}^-$ assignment, however, has been made from experiments using polarized deuterons[21,22] and polarized neutrons.[23] In view of this contradiction, the suggestion has been made[1,21,22] that there are two unresolved levels near 3614 keV excitation. In this experiment we have reconfirmed the anisotropy of the 3614 keV $\rightarrow$ 0 transition.

The 3676-keV level is observed only in the (d,p) reaction and an l_n value was not determined. The angular-correlation results in Table I allow $\frac{3}{2} \leq J \leq \frac{9}{2}$.

Our previous results[1] proposed a doublet at 3731 and 3740 keV. One or both of these levels is observed with $l_n = 2$ in the (d,p),[2] $(^3He, \alpha)$,[5] and (p,d)[6] reactions. It is also seen in the $(^3He, p)$ reaction[3,4] and a $[d_{3/2}{}^{-1}(\frac{3}{2}, \frac{1}{2}) f_{7/2}{}^2(1,0)]_{3/2^+}$ configuration is suggested. The angular-correlation information gives no limitation on spin assignments for these levels.

Levels above 3740 keV

No angular-correlation information for these levels was obtained; however, decay schemes and some branching ratios of levels up to 4534 keV are given in Table I and Fig. 2.

IV. SUMMARY

Angular-correlation and branching-ratio information has been presented on 28 levels in ^{41}Ca up

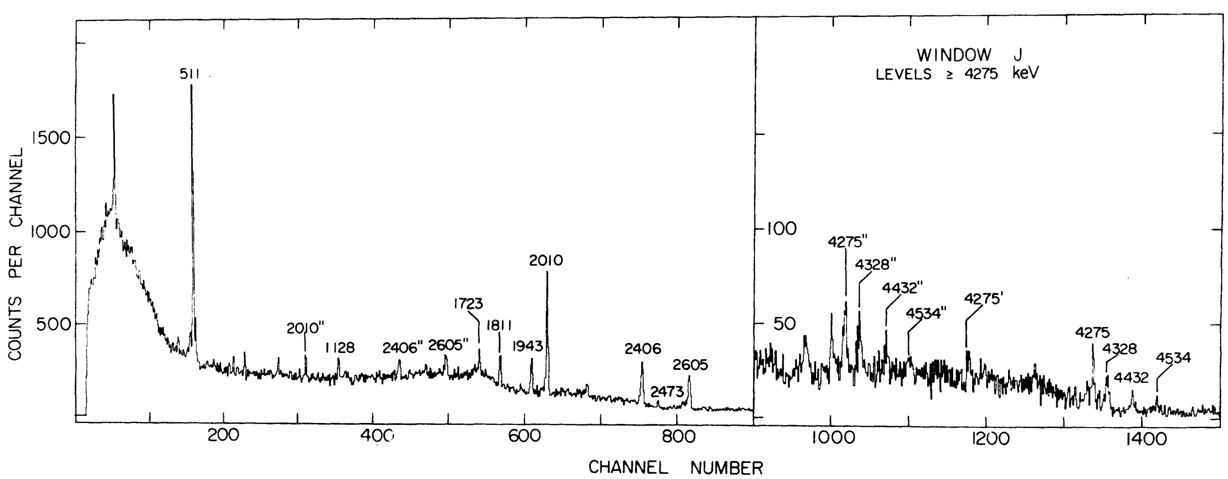

FIG. 7. Energy spectrum of γ rays in coincidence with protons in window J. The energy dispersion is 3.2 keV/channel. The notation is the same as in Fig. 3.

to 4534-keV excitation energy. Previously unreported transitions are the following (all energies in keV): 3050 → 2670 (380), 3495 → 3050 (445), 3495 → 0 (3495), 3526 → 2010 (1516), 3526 → 2760 (856), 3845 → 1943 (1902), 3845 → 2010 (1853), and the 3970 → 2605 (1365). The angular-correlation data provided no definite spin assignments but did restrict possible multipole mixing ratios in many cases. There was general agreement with previous branching-ratio and angular-correlation results, however, several discrepancies exist as shown in Table I.

*Work supported in part by the National Science Foundation.

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