PHYSICAL REVIEW C VOLUME 25, NUMBER 3 MARCH 1982

High spin states in the doubly odd ^{72}Br nucleus

G. Garcia Bermudez,* C. Baktash, and A. J. Kreiner†
Department of Physics, Brookhaven National Laboratory, Upton, New York 11973

M. A. J. Mariscotti
Departamento de Fisica, Comision Nacional de Energia Atomica, 1429 Buenos Aires, Argentina
(Received 6 October 1981)

States of ^{72}Br were studied through the ^{58}Ni(^{16}O,np) reaction at $E=40$ to 55 MeV. From the excitation function, γ-ray angular distribution, γ-γ coincidence and decay measurements, γ rays depopulating states with probable spin values ranging up to $I=(9)$ were found. An isomeric state of $T_{1/2}=10.3\pm0.6$ sec, and $I^{\pi}=(1^{-})$ at 101.0 keV excitation energy was found. The observation of certain similarities with a recently reported band in ^{74}Br suggests that the collective features seen in heavier Br isotopes may persist in ^{72}Br.

[NUCLEAR REACTIONS ^{58}Ni(^{16}O,np)^{72}Br, $E=40-55$ MeV. Measured E_γ, I_γ, $I_\gamma(t)$, $I_\gamma(\theta)$, γ-$\gamma(t)$. ^{72}Br deduced levels, I^{π}. Enriched Ni target. Ge(Li) detectors.]

I. INTRODUCTION

In connection with the systematic study of doubly-odd Br nuclei at high angular momentum, the results on ^{72}Br are presented here. From the investigation of the neighboring even-even Se and Kr isotopes, it can be deduced that this mass region exhibits a moderate deformation reflected in the structure of odd-even nuclei by the presence of decoupled $\Delta I=2$ and $\Delta I=1$ bands built on the $g_{9/2}$ orbital. In the doubly-odd nuclei, states of $I^{\pi}=4^{+}$ assigned as members of the $\tilde{\pi}g_{9/2}\otimes\tilde{\nu}g_{9/2}$ structure have been found in ^{78}Br,[1] ^{76}Br,[2] and ^{74}Br (Ref. 3) [the parity of the bandhead is not yet established in the case of ^{74}Br (Ref. 4)]. Built on this state, $\Delta I=1$ rotational bands up to spin 11 (Refs. 3 and 5) have been determined for ^{74}Br and ^{76}Br. The band in ^{76}Br has been successfully described assuming two noninteracting quasiparticles coupled to a rigid rotor,[6] an approach which explains the observed staggering of the band to be due to distortion produced by the Coriolis force. The Nilsson orbitals, mainly relevant for the interpretation of the latter effect in ^{76}Br, are characterized by $\Omega_p=\frac{1}{2}$, $\frac{3}{2}$ and $\Omega_n=\frac{5}{2}$ (all of $g_{9/2}$ parentage) for protons and neutrons, respectively. Therefore, the contributing K values for the lowest energy states are $K=|\Omega_p\pm\Omega_n|=1$, 2, 3, and 4. The above mentioned calculation favors $I^{\pi}=4^{+}$ for the bandhead, in agreement with the experimental results. The lighter ^{74}Br reveal a similar Coriolis-distorted band structure in which the behavior of the energy spacings along the band is gradual and it follows the change in deformation. Until now little information existed about excited levels of ^{72}Br and only some low spin states ($I=1$) determined from the decay of ^{72}Kr (Refs. 7 and 8) were previously known. Furthermore, Collins *et al.*,[9] studying the decay of ^{72}Br to levels of ^{72}Se, proposed $I=(3)$ for the spin of the ground state of ^{72}Br. In an effort to explore the interesting phenomena mentioned above, we investigated the high spin states of ^{72}Br.

II. EXPERIMENTAL PROCEDURE AND RESULTS

The high spin states of ^{72}Br were studied using the reaction ^{58}Ni(^{16}O,np)^{72}Br induced by an ^{16}O beam from the Brookhaven National Laboratory tandem accelerator at energies between 40 and 55 MeV. The target used was an enriched nickel (99.9%) foil of 1.5 mg/cm^2 thickness backed with 8 mg/cm^2 of natural lead to stop the recoiling nuclei. The spectra were obtained with two Ge(Li) detectors at 90° with respect to the beam axis. To select the appropriate beam energy, i.e., to obtain the maximum cross section for the production of ^{72}Br compatible with a low background in the singles spec-

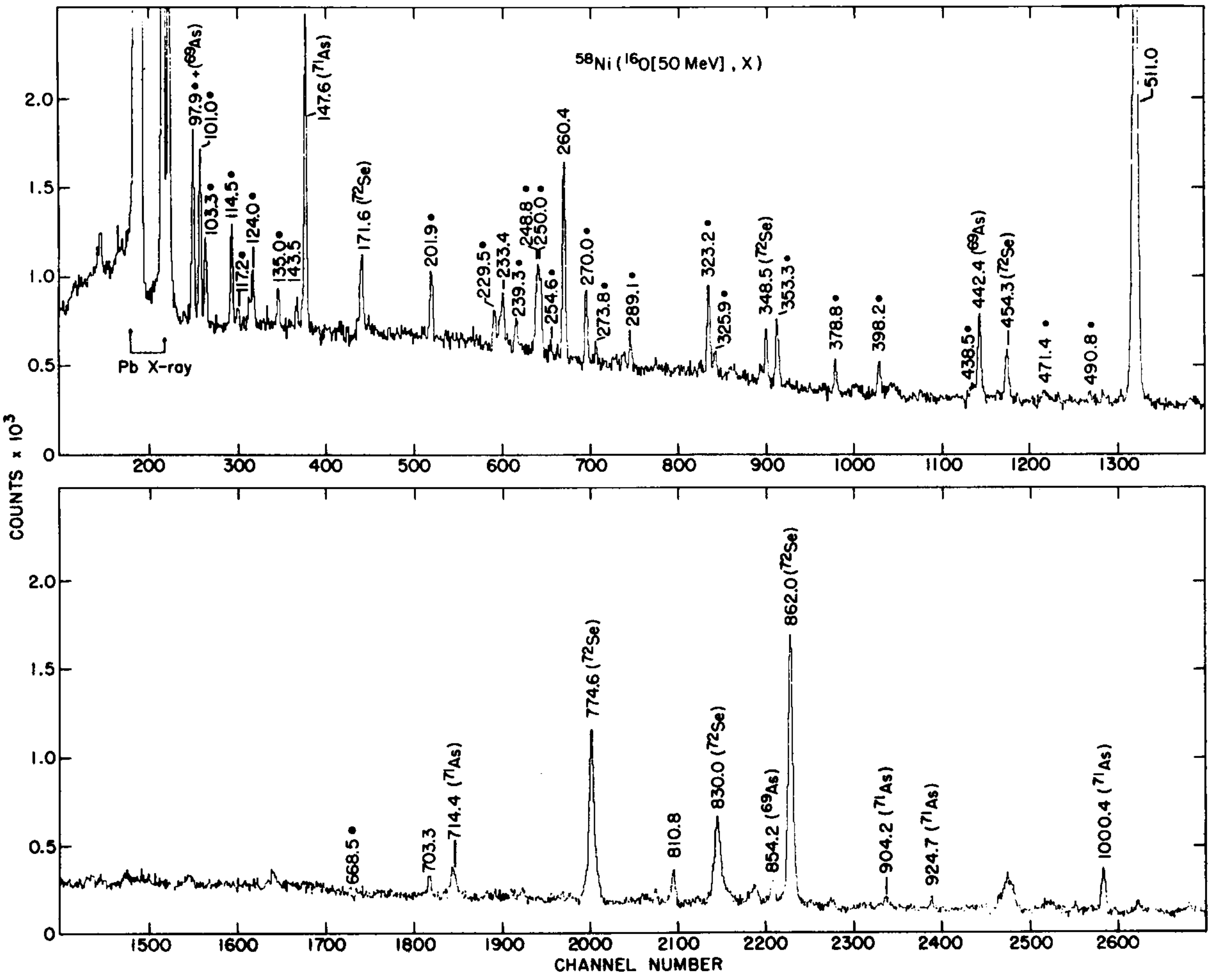

FIG. 1. Singles gamma-ray spectrum from the ^{58}Ni(^{16}O,X) reaction at 50 MeV beam energy. Solid dots indicate transitions assigned to ^{72}Br.

TABLE I. Relative coincidence intensities for the 398.2 keV group. The experimental values (upper row) are compared to the expected values (lower row, in parentheses) obtained by assuming the level scheme of Fig. 2. The numbers are normalized to the intensity of the 398.2 keV line in coincidence with the 270.0 keV gate. The letter W denotes weak intensities (less than 2 units).

Gate \ E_γ	87.8	103.3	124.0	162.2	299.5	235.6	254.6	270.0	273.8
124.0		2					5	8	12
		(4)					(10)	(13)	(16)
270.0	2	13	11	3		6			14
	(2)	(15)	(13)	(5)		(5)			(13)
273.8		4	10					14	
		(3)	(16)					(13)	
323.2	4	21	12	2	8	4	4	51	17
	(2)	(29)	(15)	(4)	(7)	(4)	(5)	(51)	(11)
353.3	4	18	10	4	9	3	3	37	11
	(2)	(29)	(13)	(3)	(6)	(3)	(4)	(41)	(9)
398.2		9						44	
		(10)						(40)	

trum, excitation functions were measured. The only indication of the production of ^{72}Br is through the 1.3 min decay to levels of ^{72}Se. Therefore, singles spectra were collected at each beam energy, from 40 to 55 MeV in 5 MeV steps, during 15 min intervals. Immediately after the irradiation was stopped, singles spectra for intervals of 1 min during 7 min were accumulated. The analysis of the prompt and decay measurements established that 50 MeV was the most suitable beam energy. Figure 1 shows a singles spectrum in which the origin of the strongest peaks is indicated. The γ-γ coincidence experiment was performed at 50 MeV beam energy and from the analysis, two groups of γ rays were found. These two groups will be identified from now on by the energies of the strongest transitions feeding the lowest state, namely, 30.4 and 398.2 keV. The results of the coincidence measurements are shown in Tables I and II. Gamma-ray angular distributions were measured using standard procedures, with a cylindrical chamber and a pair of detectors placed at a distance of 15 cm from the target. One of the detectors was held fixed for normalization purposes. The measured angles were 65°, 80°, 90°, 110°, 125°, 135°, 150°, and 160°. The results of the singles and angular distribution measurements are given in Table III and the level scheme is shown in Fig. 2.

A. Isotopic identification

Several residual nuclei are produced in the ^{58}Ni(^{16}O,X) reaction at 50 MeV energy which makes the isotopic identification complicated. Robinson *et al.*[10] studied experimentally the cross section of this reaction in the 36–46 MeV energy range and established that the strongest channel is $2p$ and, to a lesser extent, pn, αn, αp, $3p$, $p2n$, and $2pn$. The information available on ^{69}As,[11] ^{71}As,[12] and ^{72}Se (Ref. 13) allows the identification of several transitions in the singles spectrum shown in Fig. 1. Therefore, the problem reduces to distinguishing γ rays corresponding to the pn channel leading to ^{72}Br, from those belonging to the αn, $2pn$, and $2np$ channels which populate unknown high spin states in ^{69}Se, ^{71}Se, and ^{71}Br, respectively. To this end, several cross bombardments, excitation functions, and decay measurements were performed. To guide the study of the decay properties of compound nuclei in the vicinity of ^{72}Br for different target-projectile combinations the evaporation code CASCADE was used. In the following, we discuss how the different channels leading to unknown high spin states in ^{69}Se, ^{71}Br, and ^{71}Se were investigated in order to establish the isotopic assignment for the 30.4 and 398.2 keV groups.

1. ^{58}Ni(^{16}O,αn)^{69}Se. The total yield of ^{69}Se was estimated from its decay to levels of ^{69}As, and compared with the total intensity of the 30.4 and 398.2 keV groups. Due to the short half-life of ^{69}Se (27.4 sec), the measurement was performed in the following way. A singles spectrum following the ^{58}Ni(^{16}O,X) reaction at 50 MeV energy was accumulated for a period of 3 min. Immediately after the beam was stopped, decay spectra were collected at 15 sec intervals for a total duration of 6 min.

TABLE I. *(Continued.)*

289.1	297.4	310.0	323.2	334.8	353.3	278.8	398.2	438.5	668.5
4			11		10				
(6)			(15)		(13)				
		W	53		36		40		
		(2)	(51)		(41)		(40)		
			14		12				
			(11)		(9)				
24	3	*W*		9	71	18	34	7	10
(22)	(3)	(2)		(7)	(81)	(17)	(34)	(7)	(10)
18	*W*	*W*	76	4		15	26	6	15
(18)	(2)	(2)	(81)	(6)		(14)	(28)	(6)	(8)
			32		25				
			(34)		(28)				

TABLE II. Relative coincidence intensities for the 30.4 keV group. For explanation see Table I.

Gate \ E_γ	86.9	97.9	114.5	117.2	135.0	152.2	201.9	239.3
86.9		3 (3)	20 (32)		5 (7)	2 (5)		
97.9	W (3)		3 (2)	W (0.3)		2 (2)	2 (2)	10 (9)
114.5	20 (32)	W (2)		4 (4)	6 (7)			
135.0	4 (7)		6 (7)	W (1)			6 (8)	
201.9		W (2)			7 (8)			
239.3		8 (9)						
248.8 + 250.0	57 (98)	6 (11)	W (6)	7 (13)	8 (11)	2 (1)	4 (6)	10 (7)

This cycle was repeated so as to obtain enough intensity in the 66.4 and 98.2 keV γ rays originating from the decay of ^{69}Se. Taking the sum total intensity of the 30.4- and 398.2-keV group to be 100, we obtained 52 ± 6 and 48 ± 6 for their relative intensities, respectively. The corresponding number for ^{69}Se, calculated from its 27.4 sec decay, was 5 ± 2. Therefore, comparing these results, it is clear that the 30.4 and 398.2 keV groups cannot populate levels in ^{69}Se.

2. $^{58}Ni(^{16}O,2np)^{71}Br$. Since the level scheme of ^{71}Br as well as its decay to levels of ^{71}Se are not known, it was necessary to use cross bombardment arguments. The evaporation code CASCADE indicated that the ^{40}Ca(^{35}Cl,X) reaction ($E=95$ MeV) produced ^{72}Br, and not ^{71}Br with sizable cross sections through the $2pn$ and α channels, respectively. Therefore, excitation function and decay measurements, using ^{40}Ca(^{35}Cl,X) at 95 and 105 MeV beam energies, were performed. A target of 0.5 mg/cm^2 of ^{40}Ca with a backing of 5 mg/cm^2 thickness of natural Pb was used. From the decay experiment we estimated the yield at ^{72}Br by measuring the intensity of the 862.0 keV transition in ^{72}Se populated by the decay of the 1.3 min state in ^{72}Br. The ratio of the ^{72}Br yield to the intensity of each of the 30.4 and 398.2 keV groups of γ rays was found to be similar to that obtained from the study of the ^{58}Ni(^{16}O,X) reaction. These observations suggest that neither the 30.4 keV nor the 398.2 keV groups populate levels of ^{71}Br.

3. $^{58}Ni(^{16}O,2pn)^{71}Se$. Using the above procedure the ^{58}Ni(^{19}F,X) reaction ($E=45-60$ MeV) was investigated. This reaction is expected to produce ^{71}Se but not ^{72}Br, through the αnp and αn reaction channels, respectively. The decay of ^{71}Se to ^{71}As ($T_{1/2}=4.9$ min) was followed at different beam energies through the observation of the 147.2 keV transition. No evidence for the decay of ^{72}Br (1.3 min) was found. These results, which are in agreement with the CASCADE predictions, together with the absence of γ rays belonging to the 30.4 and 398.2 keV groups, reveal that these groups do not populate levels of ^{71}Se.

In conclusion, these results suggest that the 30.4 and 398.2 keV groups of γ rays correspond to the decay of excited states in ^{72}Br. Further evidence supporting the isotopic assignment will be given in Sec. III. Another interesting result from the above decay measurements was the observation that the intensity ratio of the 101.0 keV transition to the 30.4 and 398.2 keV groups is approximately constant. The characteristics of this transition will be discussed in the next section.

B. The 101.0 keV isomer

The coincidence measurements determined that the 101.0 keV transition is not in coincidence with any other γ ray, supporting the idea that this transition deexcites a state of long half-life ($T_{1/2}$ greater

TABLE II. *(Continued.)*

241.8	248.8	250.0	297.4	325.9	334.8	471.4	490.8
3 (2)		61 (98)	*W* (1)	10 (13)	3 (3)	10 (15)	8 (10)
W (0.5)	11 (11)					3 (4)	2 (2)
W (0.2)	3 (5)		*W* (0.4)	14 (14)	5 (4)	*W* (2)	*W* (1)
W (0.5)	6 (11)					3 (4)	2 (2)
W (0.3)	6 (6)		*W* (0.4)	20 (16)	4 (4)	2 (3)	3 (2)
2 (0.3)	8 (7)		2 (2)			*W* (2)	3 (3)
8 (5)		76 (86)				24 (38)	10 (10)

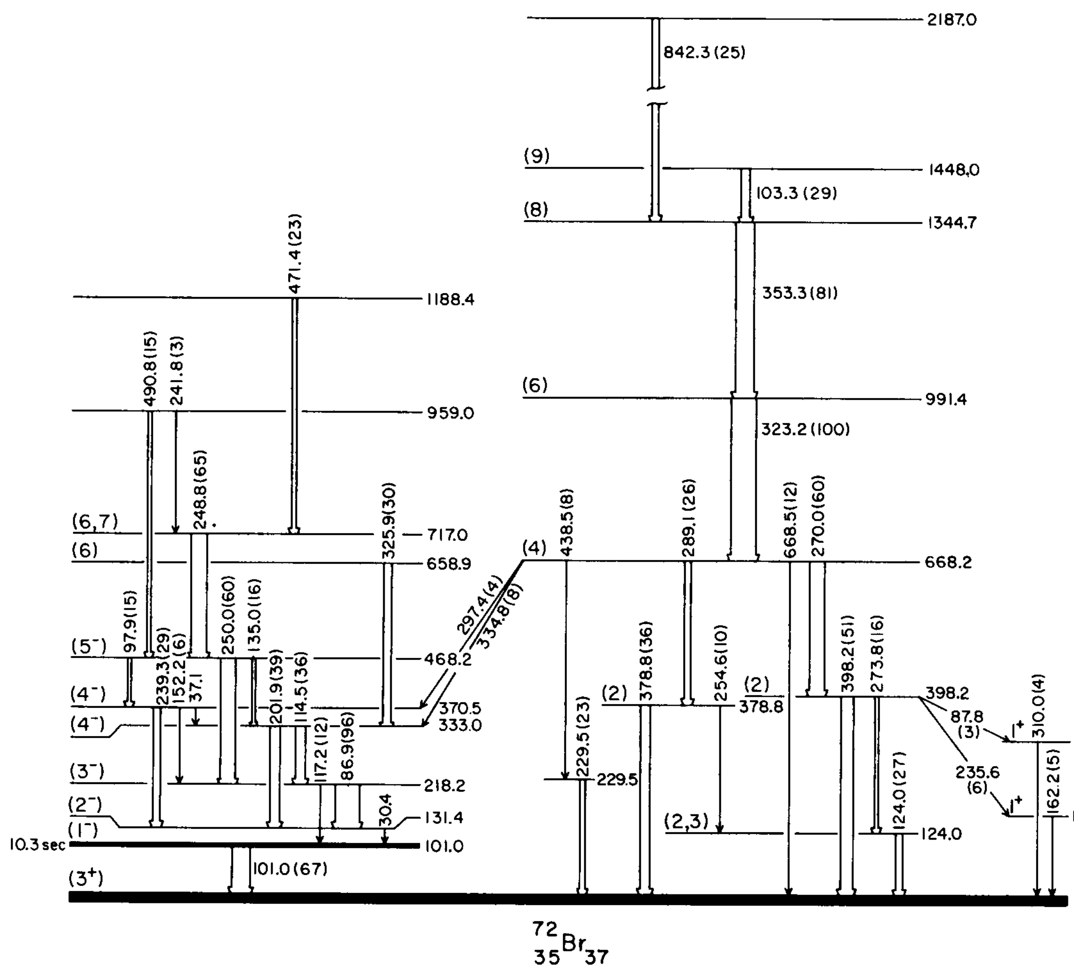

FIG. 2. Level scheme for ^{72}Br. Two groups of γ rays, identified by the energies of the strongest transitions feeding the lowest state, namely 30.4 and 398.2 keV, are shown. For the intensity of the low energy, 30.4 and 37.1 keV transitions, see Table III.

TABLE III. Energies, intensities, and angular distribution coefficients of γ rays assigned to the ^{58}Ni(^{16}O,np)^{72}Br reaction at 50 MeV energy. The errors in the last numeral are given in parentheses.

E_γ (± 0.3) (keV)	I_γ[a]	A_2	A_4
30.4	>164[b]		
37.1	11[d]		
86.9	96		
87.8	3[c]		
97.9	15[c]		
101.0	67		
103.3	29	−0.22(4)	0.09(7)
114.5	36	−0.18(4)	0.06(6)
117.2	12	0.4(1)	0.1(2)
124.0	27	0.28(4)	−0.07(6)
135.0	16		
152.2	6[c]		
162.2	5[c]		
201.9	39	0.36(4)	−0.02(6)
229.5	23	0.46(8)	0.04(12)
235.6	6[c]		
239.3	29	0.24(6)	0.1(2)
241.8	3		
248.8	65	0.15(5)	−0.02(7)
250.0	60	0.34(4)	−0.12(8)
254.6	10		
270.0	60	0.41(3)	−0.08(5)
273.8	16		
289.1	26	0.34(8)	−0.05(12)
297.4	4[c]		
310.0	4[c]		
323.2	100	0.38(3)	−0.17(6)
325.9	30	0.36(8)	−0.08(14)
334.8	8[c]		
353.3	81	0.37(3)	−0.14(6)
378.8	36	0.22(7)	0.0(1)
398.2	51	0.23(6)	−0.05(9)
438.5	8		
471.4	23		
490.8	15		
668.5	12[c]		
842.3	25		

[a]The intensities are normalized to that of the 323.2 keV transition. The errors are 5% for the strongest peak and 40% for the weaker ones.
[b]Estimated total intensity from the decay scheme.
[c]Estimated from the coincidence results. The errors are 30%.
[d]Estimated total intensity from the coincidence results.

than 200 nsec). Davids *et al.*,[7] in their study of the 17.2 sec decay of ^{72}Kr to levels of ^{72}Br, reported a γ ray of 101.3±0.4 keV energy decaying with a half-life of 21.9±1.9 sec. The observed difference in the half-lives made the assignment of the 101.3 keV transitions to ^{72}Br doubtful, for which reason they ignored its origin. These evidences prompted our search for an isomeric transition in the sec time range using a pulse beam of ^{16}O ($E = 50$ MeV) on a ^{58}Ni target. Singles spectra were collected for an irradiation period of 1 min. Immediately after the beam was stopped, additional singles spectra were accumulated for intervals of 5 sec, to study the decay. This cycle was repeated to obtain sufficient intensity in the 101.0 keV transition. The results for the decay of 101.0 keV transition, shown in Fig. 3, indicated a half-life of 10.3±0.6 sec. To explore the possibility of this transition being the same as the one observed by Davids *et al.*[7] which showed a 21.9 sec half-life, we made the following calculation. We assumed that the 101.0 keV transition deexcited a level of 10.3 sec half-life in ^{72}Br, which in turn is populated by the decay of 17.2 sec state in ^{72}Kr. The combined decay curves are shown in Fig. 3 (dashed line). The circles indicate the time intervals used by Davids *et al.*[7] in their ^{72}Kr decay experiment, and the superimposed line represents a 21.9 sec half-life. As can be seen, the agreement is fairly good, supporting the idea that both transitions, the one from the decay of ^{72}Kr and the one from the in-beam study, are the same. To study the relation between this transition and the already established 30.4 and 398.2 keV groups, the excitation function of the ^{58}Ni(^{16}O,X) reaction between 40 and 55 MeV was analyzed. In Fig. 4 we show the yield of the predominant transitions in the 30.4 and 398.2 keV groups normalized to the 398.2 keV transition and set equal to one at 45 MeV beam energy. As is shown, the yield of the 101.0 keV transition follows the trend of the 30.4 keV group (represented by the 250.0 plus 248.8 keV and 201.9 keV yield curves), and not that of the 398.2 keV group. The relation between the 101.0 keV transition and the 30.4 keV group will be discussed in the next section.

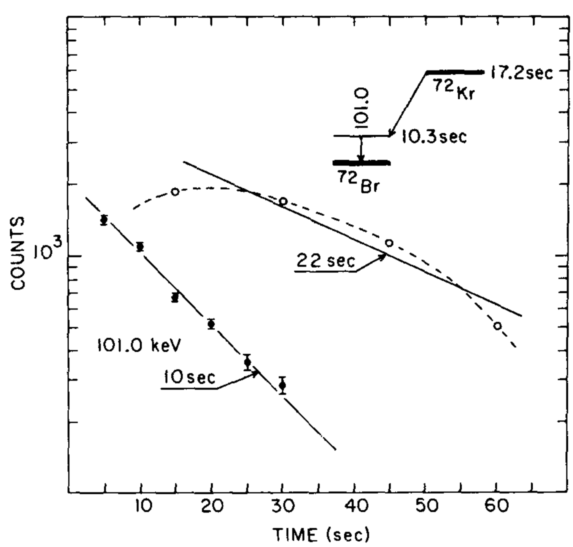

FIG. 3. Decay curve for the 101.0 keV transition measured after the irradiation of a ^{58}Ni target with 50 MeV ^{16}O beam. The dashed line is obtained assuming the decay path shown in the inset. For details, see text.

III. THE LEVEL SCHEME

As mentioned above, two groups of γ rays and a 101.0 keV transition with 10.3±0.6 sec half-life have been suggested to originate from the decay of excited states of ^{72}Br. From the coincidence experiments, two weak transitions, namely the 297.4 and 334.8 keV, were established. These two transitions (see Fig. 2) connect the 30.4 and 398.2 keV groups and in turn determine the existence of a state at 101.0 keV energy in the decay of ^{72}Br. This latter result together with the previously noted relationship between the excitation function of the 101.0 keV transition and the 30.4 keV group of γ rays suggest that the 30.4 keV group populate the ground state through the isomeric transition of 101.0 keV energy. Another result seen in Fig. 2 is the population of the $I^{\pi}=1^{+}$ levels at 310.0 and

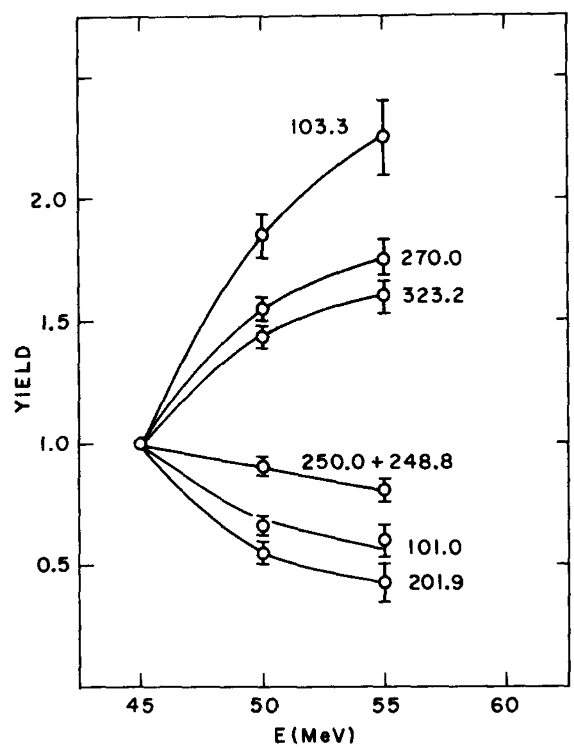

FIG. 4. Excitation function of some transitions in ^{72}Br between 45 and 55 MeV energy. The intensities are normalized to that of the 398.2 keV transition at 45 MeV beam energy. The yield of transitions corresponding to the 30.4 and 398.2 keV groups shows different behavior. As is shown, the 101.0 keV transition, deexciting the isomeric state, follows the trend of the 30.4 keV group.

162.2 keV energy. These levels had already been determined as excited states of ^{72}Br from the ^{72}Kr decay measurement.[7,8] This result provides independent evidence in support of our isotopic assignment. Recently, Herath-Banda *et al.*[14] assigned several γ rays to ^{72}Br in a neutron-gamma coincidence experiment. Several of them are in agreement with transitions deexciting levels of the 398.2 keV group. A discussion of the properties of each group of γ rays follows.

A. The 398.2 keV group

Collins *et al.*,[9] studying the decay of ^{72}Br to levels of ^{72}Se, suggested $I=(3)$ for the ground state of ^{72}Br. Lifetime arguments, namely the presence of prompt transitions between the 1^+ states at 310.0 and 162.2 keV energy to the $I=(3)$ ground state, suggest an $E2$, rather than $M2$, character for these transitions. Therefore, $I^\pi=(3^+)$ for the ground state of ^{72}Br is proposed. Similarly, the presence of a prompt 87.8 keV transition between the states at 398.2 and 310.0 keV excitation energies argues against an $E2$ character, thus leading to $I=(1,2)$ assignment for the state at 398.2 keV energy.

Angular distribution measurements (see Table III) show that the strong cascade of 353.3, 323.2, and 270.0 keV γ rays proceeds through quadrupole transitions. In addition, the absence of crossovers suggests that the cascade is a $\Delta I=2$ type. Assuming $I^\pi=(2)$ for the 398.2 keV level, the spins for the 668.2, 991.4, and 1344.7 keV levels are (4), (6), and (8), respectively. From the angular distribution coefficient of the 353.3 keV [$(8)\rightarrow(6)$] and 323.2 keV [$(6)\rightarrow(4)$] transitions, the attenuation coefficients $\alpha_2=0.84\pm0.03$ and $\alpha_4=0.7\pm0.2$ were determined. [These attenuation coefficients will not change significantly, if one assumes $I=(1)$ for the state at 398.2 keV.] Using the above value for α_2, we obtain $A_2^{\max}\geq 0.27\pm0.08$ for the angular distribution coefficient of the 398.2 keV transition. Since the theoretically calculated value of $A_2^{\max}$ for a $1\rightarrow3$ transition is 0.14, the choice of $I=1$ for the state at 398.2 keV is ruled out. Similar arguments lead to the assignment of $I=(2)$ for the state at 378.8 keV.

B. The 30.4 keV group

This group of γ rays was suggested to decay to the ground state through the 101.0 keV transition. Therefore, to determine the multipolarity of the 101.0 keV transition, decay measurements were performed, using the ^{58}Ni[^{16}O(50 MeV),X] reaction. The internal conversion coefficient was determined by comparing the total yield of ^{72}Br (normalized to 100) as obtained from its decay to ^{72}Se, with the intensities of the 30.4, 398.2 groups and the 101.0 keV transition. From in-beam measurements, the latter intensities were determined as 51 ± 10, 47 ± 10, and 20 ± 1, respectively. The sum total intensity of the two groups (=98) accounts practically for all the intensity of ^{72}Br (=100), revealing that any side feeding to the lowest levels is negligible. From intensity balance arguments a range of values of $0.9<\alpha_T<2.5$ for the total conversion coefficient of the 101.0 keV transition was obtained. The theoretical values are $E2$:0.77, $M2$:1.14, $E3$:7.25, and $M3$:11.5 and show that the experimental results are consistent with $M2$. This suggestion of $M2$ character for the 101.0 keV transition deexciting a level of 10.3 sec half-life, entails a retardation factor of 10^5 compared to the single particle estimate. A similar, highly retarded $M2$ transition (57 keV energy, $T_{1/2}=1.3$ sec) has been found in the decay of the neighboring nucleus ^{76}Br (Ref. 2). Hence, an $I^\pi=(1^-)$ for the isomeric state at 101.0 keV energy is proposed. Assignment of $I^\pi=(5^-)$ to this state is not likely in view of the presence of 297.4 and 334.8 keV intergroup transition [which depopulate an $I=(4)$ state], as well as the observation of a 101.0 keV isomeric transition in the decay of the $I^\pi=0^+$ state in ^{72}Kr (Ref. 7). The cascade of γ rays through the levels $468.2\rightarrow333.0\rightarrow218.2\rightarrow131.4\rightarrow101.0$ keV reveals a simple pattern of direct and crossover transitions characteristic of a $\Delta I=1$ band. The angular distribution measurement, together with the fact that the 30.4 keV transition has been seen in coincidence with other γ rays, suggest a dipole character, resulting in the indicated spins.

IV. DISCUSSION AND CONCLUSIONS

As mentioned in the Introduction, the search for high spin states in the Br region revealed interesting features. Positive parity states of $g_{9/2}$ parentage have been observed in ^{78,76}Br (Refs. 1 and 2) and suggested in ^{74}Br (Ref. 3). Starting with ^{78}Br, which shows a multiplet of states originating from the $\tilde{\pi}g_{9/2}\otimes\tilde{\nu}g_{9/2}$ configuration, these states continue to exist toward lighter isotopes, namely ^{76}Br and ^{74}Br, where a Coriolis distorted $\Delta I=1$ rotational band has been found. An unambiguous identification of such states has not been achieved in the present work but some evidence suggesting their existence has been obtained. Shown in Fig. 2 is a cascade of intense quadrupole transitions with energies of 353.3, 323.2, and 270.0 keV. This cascade decays to the known 1^+ states at 310.0 and 162.2 keV energy, and populates the $I^{\pi}=(3^+)$ ground state. These facts suggest the possibility that these γ rays deexcite positive parity states that could be associated with the high spin intrinsic $\tilde{\pi}g_{9/2}\otimes\tilde{\nu}g_{9/2}$ configuration. To further explore this idea, we have plotted the excitation energy versus $I(I+1)$ (Fig. 5) for some of the ^{72}Br levels, together with similar plots for the members of the positive parity band in ^{74,76}Br up to spin 9. An interesting feature shown in this figure is the linear relationship between the level energy and angular momentum of the members of the cascade populating the $I^{\pi}=(1^-)$ isomeric state in ^{72}Br. The levels at 398.2, 668.2, and 991.4 keV energy also lie approximately on a straight line whose slope (related to the moment of inertia) is similar to that of the ^{74}Br. The higher states in the cascade, namely those at 1344.7 and 1448.0 keV energy, reveal a progressive deviation from a linear behavior. This similarity with ^{74}Br is encouraging and to investigate this tentative interpretation, more experimental and theoretical work would be necessary.

In summary, the main results of this work are

(a) the determination of an isomeric state of 10.3 sec half-life at 101.0 keV energy;

(b) the observation of ^{72}Br states with probable spin values up to $I=(9)$;

(c) the observation of similarities with recently reported bands in ^{74}Br and ^{76}Br which suggest that the collective features seen in heavier Br isotopes may persist in ^{72}Br.

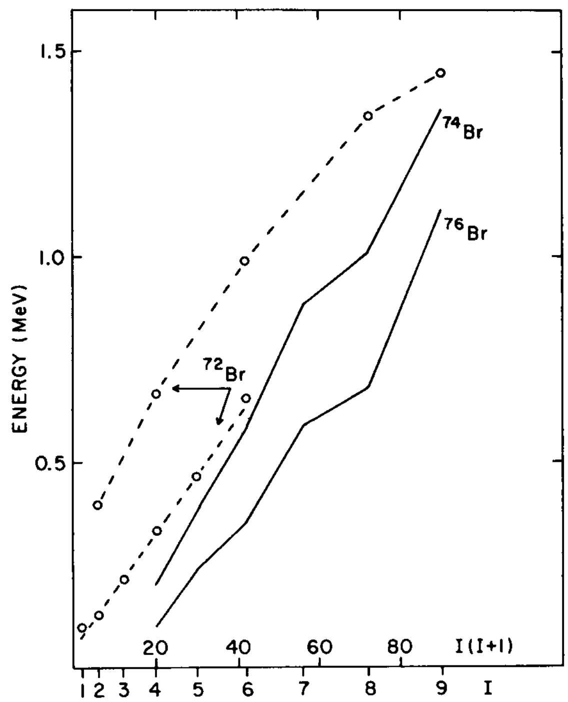

FIG. 5. Plot of the excitation energies as a function of $I(I+1)$ for some of the ^{72}Br levels (dashed line) compared to that of ^{74,76}Br up to spin 9 (solid line). For details, see the text.

ACKNOWLEDGMENTS

This work was carried out under the auspices of Consejo Nacional de Investigaciones Cientificas y Tecnicas, Argentina, the National Science Foundation, and the U. S. Department of Energy, Contract No. DE-AC02-76CH00016. One of us G.G.B., is a fellow of the Consejo Nacional de Investigaciones Cientificas y Tecnicas.

*On leave from Comision Nacional de Energia Atomica, 1429 Buenos Aires, Argentina.

†Present address: Comision Nacional de Energia Atomica, 1429 Buenos Aires, Argentina.

[1]G. Garcia Bermudez, D. Abriola, M. Behar, M. C. Berisso, J. Fernandez Niello, A. Filevich, and M. A. J. Mariscotti, J. Phys. G 6, L89 (1980); M. Behar, D. Abriola, A. Filevich, G. Garcia Bermudez, A. J. Kreiner, and M. A. J. Mariscotti, in Proceedings of the International Conference on Nuclear Physics, Berkeley, California, 1980, LBL Report No. LBL-11118, p. 167.

[2]M. Behar, A. Filevich, G. Garcia Bermudez, and M. A. J. Mariscotti, Nucl. Phys. A282, 331 (1977); A. J. Kreiner, G. Garcia Bermudez, M. A. J. Mariscotti, and P. Thieberger, Phys. Lett. 83B, 31 (1979).

[3]G. Garcia Bermudez, A. Filevich, A. J. Kreiner, M. A. J. Mariscotti, C. Baktash, E. der Mateosian, and P. Thieberger, Phys. Rev. C 23, 2024 (1981).

[4]C. Ekström and L. Robertsson, Phys. Scr. 22, 344 (1980).

[5]J. C. Wells, R. L. Robinson, H. J. Kim, R. O. Sayer, R. B. Piercey, A. V. Ramayya, J. H. Hamilton, C. F. Maguire, K. Kumar, R. W. Eastes, M. E. Barclay, and A. J. Caffrey, Phys. Rev. C 24, 171 (1981).

[6]A. J. Kreiner and M. A. J. Mariscotti, Phys. Rev. Lett. 43, 1150 (1979).

[7]C. N. Davids and D. R. Goosman, Phys. Rev. C 8, 1029 (1973).

[8]H. Schmeing, J. C. Hardy, R. L. Graham, J. S. Geiger, and K. P. Jackson, Phys. Lett. 44B, 449 (1973).
[9]W. E. Collins, J. H. Hamilton, R. L. Robinson, H. J. Kim, and J. L. C. Ford, Phys. Rev. C 9, 1457 (1974).
[10]R. L. Robinson, H. J. Kim, and J. L. C. Ford, Phys. Rev. C 9, 1402 (1974).
[11]H. P. Hellmeister, E. Schmidt, M. Uhrmacher, R. Rascher, K. P. Lieb, and D. Pantelica, Phys. Rev. C 17, 2113 (1978).
[12]B. Heits, H. G. Friederichs, A. Rademacher, K. O. Zell, P. von Brentano, and C. Protop, Phys. Rev. C 15, 1742 (1977).
[13]F. Kerns and J. N. Mo, Nucl. Data Sheets 31, 103 (1980).
[14]M. A. Herath-Banda *et al.*, Bull. Am. Phys. Soc. 26, 90 (1981).