Band structure in ^{78}Rb

M. A. J. Mariscotti and G. García Bermúdez
Departamento de Física, Comisión Nacional de Energía Atómica, Buenos Aires 1429, Argentina and Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brasil

J. C. Acquadro, A. Lepine, M. N. Rao, and W. Seale
Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brasil

E. der Mateosian and P. Thieberger
Department of Physics, Brookhaven National Laboratory, Upton, New York 11973
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A level scheme is proposed for ^{78}Rb, which was obtained through the ^{64}Zn(^{16}O,np) reaction at 44 and 52 MeV, by measuring γ-γ coincidences and γ-ray angular distributions. The isotopic identification was made by studying on- and off-beam spectra at selected time intervals, and determining the intensities of the different decay products. The main part of the level scheme comprises a $\Delta I = 1$ band which shows a staggering similar to that previously found in ^{76}Br and ^{77}Kr. In addition the level energies are very close to those in ^{76}Br. It was not possible to establish in a conclusive manner whether the lowest state of the proposed level scheme corresponds to one or the other of the hitherto known 6 and 17.5 min isomers in ^{78}Rb, but the first possibility appears to be the more likely one.

[NUCLEAR REACTIONS ^{64}Zn(^{16}O,np), E=44 and 52 MeV; measured $\sigma(E_\gamma, \theta), E_\gamma, I_\gamma$, γ-γ coin. ^{78}Rb deduced levels, I. Enriched ^{64}Zn target.]

I. INTRODUCTION

The present investigation of ^{78}Rb was stimulated by recent results[1] obtained in the next lighter doubly odd $N=41$ isotone ^{76}Br. In this nucleus a band has been found[1] which shows deviations from the $I(I+1)$ law similar to those observed[2] for the $\frac{5}{2}^+$ ground state band in ^{77}Kr. In addition the first two excited states in these bands lie at very nearly the same energy. These observations suggest the possibility of an unexpected simple relationship between the intrinsic structure of such bands in spite of the fact that, outside the deformed regions, one would expect a doubly odd nucleus to exhibit a spectrum different from that of an odd-A nucleus. It seemed therefore desirable to investigate these regularities further by studying the properties of the high spin states of ^{78}Rb, the next heavier isotone.

Until now the ground state ($T_{1/2}$=17.5 min) and a 6.0 min isomer were the only known states in ^{78}Rb. Nolte and Shida[3] studied their decay and found that while the 6 min isomer feeds the 4^+ state of ^{78}Kr and, more weakly, the 6^+ state, the 17.5 min isomer feeds the 2^+ state strongly. Thus, they conclude that the former is a high spin state and the latter is a low spin state. From their deduced logft values they further infer that negative parity is favored in both cases. In addition, a 103.4 keV transition is identified as depopulating the 6 min isomer to the ground state.[3]

In the present work the ^{64}Zn(^{16}O,np) reaction has been used to reach levels in ^{78}Rb and study their γ decay. This reaction is expected to excite high spin states and is therefore appropriate to search for structures of the type found in ^{76}Br.

In the following a brief account of the experimental setup is given. In Sec. III the choice of the reaction energy and the singles γ spectra are discussed. The results of the singles, coincidence, and angular distribution measurements, pertaining to the γ transitions assigned to ^{78}Rb are summarized in Sec. IV, and in Sec. V we analyze each of the outgoing channels observed in these measurements on which the identification of the proposed level scheme is based. The last section includes a comparison of the present results with the available data on ^{76}Br and ^{77}Kr. From this comparison the main result of this paper emerges, namely that ^{78}Rb exhibits a band which is very similar to that in ^{76}Br and that, therefore, the previously noted parallelism between the latter and ^{77}Kr is extended to ^{78}Rb.

II. EXPERIMENTAL SETUP AND MEASUREMENTS

The results presented in this paper were obtained at two experimental facilities. At the Sao Paulo 8 MV Pelletron Laboratory 1 mg/cm^2 of enriched (95%) ^{64}Zn fixed to a thick natural Pb backing was used as a target. The γ-ray spectra were detected with a pair of similar ~8% efficiency Ge(Li) counters of about 2.3 keV resolution at 1.3 MeV. Events were processed through conventional electronics and accumulated in the memory of an IBM 360/44 computer.

At the Brookhaven National Laboratory Tandem facility a target of ^{64}Zn, thick enough to stop the beam, was used. Again the data were collected with two Ge(Li) detectors, but one of them was a small planar high resolution device.

The experiments involved the measurement of on- and off-beam γ-ray singles spectra, γ-γ coincidences, and γ-ray angular distributions.

III. CHOICE OF BOMBARDING ENERGY AND SINGLES SPECTRA

Since no information on prompt γ rays of ^{78}Rb was available, an estimate of the optimum energy for the $^{64}Zn(^{16}O, np)$ reaction was deduced from published cross section data[4,5,6] of $(^{16}O, xnypz\alpha)$ reactions on targets of $^{63,65}Cu$ and $^{58,60,61}Ni$. By using the variable $\delta = A - 1.7N$ which measures the degree of neutron deficiency,[7] it was possible to combine the results for different targets and different energies and obtain interpolated values for neighboring nuclei such as ^{64}Zn.

Owing to the Coulomb barrier the cross section for the formation of the compound nucleus ^{80}Sr rises steeply above 37 MeV. The analysis shows that the $^{64}Zn(^{16}O, np)$ and $^{64}Zn(^{16}O, 2p)$ reactions are expected to predominate between 40 and 55 MeV. Other channels which should also contribute with less intensity in this energy range are the $(^{16}O, p\alpha)$, $(^{16}O, n\alpha)$, $(^{16}O, n2p)$, and $(^{16}O, 2np)$ reactions.

Typical singles γ-ray spectra are shown in Fig. 1. The spectrum in Fig. 1(a) was obtained at 44 MeV with a 8% Ge(Li) counter during a 44 min irradiation. Figure 1(b) corresponds to 5 min data collection after the beam was switched off at $t = 52$ min, using the same set up as above. The spectrum in Fig. 1(c) was obtained at 52 MeV with a high resolution detector and shows an improved picture of the low energy peaks and multiplets below 200 keV. The peak assignments are indicated. The multiplet at about 150 keV is well resolved, and even the two peaks at about 129 keV which belong to ^{77}Kr and ^{77}Br are separated. It can also be noted that the lines from the $^{64}Zn(^{16}O, n2p)^{77}Kr$ reaction become relatively stronger at 52 MeV.

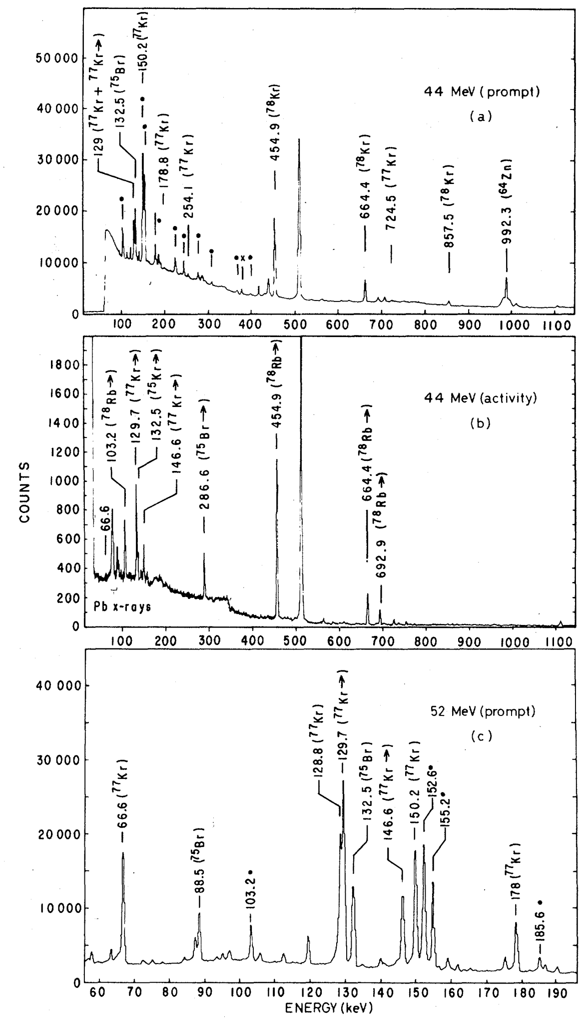

FIG. 1. Singles γ-ray spectra from the $^{64}Zn + ^{16}O$ reaction. (a) Beam-on spectrum at 44 MeV ($\Delta t = 44$ min. (b) Beam-off spectrum following 52 min irradiation at 44 MeV [$\Delta t = 5$ min, same geometry as in (a)]. (c) Beam-on spectrum at 52 MeV. The lines assigned to ^{78}Rb are indicated with solid dots. The line at 377.6 keV (indicated with a cross) is partially due to the $^{64}Zn(^{16}O, n2p)^{77}$ Kr reaction. The symbol $^{78}Rb\rightarrow$ indicates a line produced in the decay of ^{78}Rb and so on.

The dominant lines at 454.9, 664.4, and 857.5 keV correspond to the $^{64}Zn(^{16}O, 2p)^{78}Kr$ reaction,[8] although part of the intensity of these lines originates in the decay[3] of ^{78}Rb. The decay contribution was evaluated by measuring the γ-ray spectra during several time intervals up to 65 min after switching off the beam, and using previously reported data.[3] As an example, the 454.9 keV peak in Fig. 1(a) has a contribution of about 36% from the 6 min decay and 11% from the 17.5 min decay.

The available information on the decay of ^{75}Kr (Ref. 9), ^{77}Kr (Ref. 10), and on the excited states of ^{75}Br (Ref. 11) and ^{77}Kr (Ref. 2) allows us to identify the stronger lines stemming from the (^{16}O,$n\alpha$), (^{16}O,$n2p$), and (^{16}O,$p\alpha$) reactions, as indicated in Fig. 1.

In the off-beam spectrum [Fig. 1(b)] one can see the main activities produced after 52 min irradiation. These are ^{78}Rb→^{78}Kr (both 6 and 17.5 min half-lives are observed), 95 min ^{75}Br →^{75}Sr (Ref. 12), 74.7 min ^{77}Kr→^{77}Br (Ref. 10), and 4.5 min ^{75}Kr→^{75}Br (Ref. 9). The place where the unobserved 66.6 keV peak from the 3.9 min ^{77}Rb→^{77}Kr decay[13] should be if the ^{64}Zn(^{16}O, $2np$) ^{77}Rb reaction had been produced with enough intensity, is also indicated.

IV. COINCIDENCE AND ANGULAR DISTRIBUTION RESULTS

The 152.6 and 155.2 keV γ rays are the only lines among the strongest in the prompt spectrum [see Figs. 1(a) and 1(c)] which could not be identified with previously known γ transitions. Consequently, in order to establish their origin, the γ ray spectra in coincidence with these two γ rays, and subsequently, the coincidences with those lines showing in these spectra, were investigated, giving rise to the coincidence matrix shown in Table I. Some of the coincidence spectra are also shown in Fig. 2. These measurements determine a set of hitherto unknown γ rays which belong to the same nucleus. On the basis of the arguments presented in the next section these γ rays have been identified with transitions in ^{78}Rb. The energies and intensities of these γ rays are given in Table II.

The γ-ray angular distributions were measured at 52 MeV by placing a detector at angles with respect to the beam axis between 0° and 90° in steps of 15° and at 120°. The peak areas were normalized by routing suitably chosen signals from a fixed detector into a dead time correcting counter. The A_2 and A_4 coefficients, obtained by fitting the measured peak areas to the usual angular distribution function $W(\theta) = A_0(1 + A_2P_2 + A_4P_4)$, are listed in columns 4 and 5 of Table II. In addition, complementary data are shown

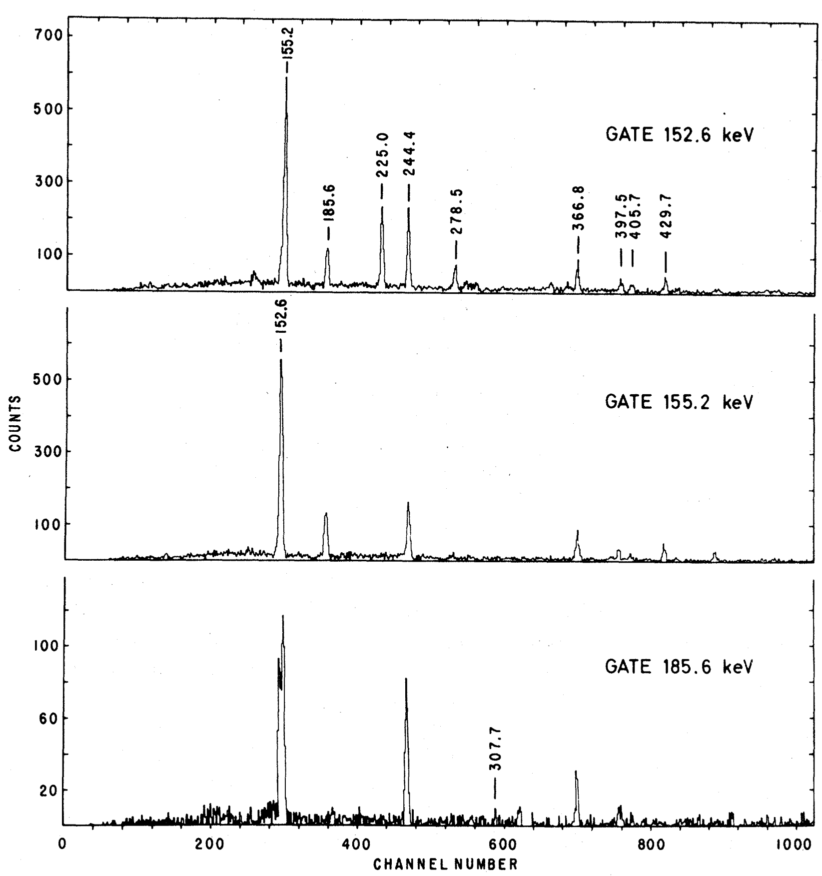

FIG. 2. Coincidence spectra gated with the 152.6, 155.2, and 185.6 keV lines.

TABLE I. Relative coincidence intensities from the $^{64}Zn(^{16}O,np)^{78}Rb$ reaction at 52 MeV. Intensities are corrected for the detector efficiency and are normalized to the total intensity depopulating the state fed by the gating transition except in the case of the 152.6 keV line. Energies are in keV. The energy region up to about 2 MeV was investigated. The values in this table have an uncertainty of about 25%.

Gate/E_γ	152.6	155.2	185.6	225.0	244.4	278.5	307.7	366.8	397.5	405.7	429.7
152.6		1	0.28	0.58	0.63	0.25	···	0.33	0.16	0.10	0.16
155.2	1		0.28	···	0.44	···	···	0.30	0.14	0.11	0.14
185.6	0.75	0.95	···	···	1	···	0.18	0.62	0.25	0.12	···
225.0	1	···	···	···	···	0.25	···	···	···	···	···
244.4	0.97	0.83	0.66	···	···	···	0.17	0.34	···	···	···

in the last column of Table II, where the anisotropy of the γ rays at 44 MeV is listed. These values were obtained by analyzing the γ-ray spectra taken with two fixed detectors at 0° and 90° and normalizing the peak areas with the 992.3 keV line from Coulomb excitation on ^{64}Zn since the angular distribution is, in this case, well known. In this way the angular distribution measurements are partially completed for the case of the weak lines. Most of the lines have negative A_2 coefficients which, together with small A_4 values, indicate $\Delta I = 1$ character. The measured positive anisotropies for the 307.7, 397.5, and 429.7 keV γ rays also suggest that these lines are of $\Delta I = 2$ type. For the 307.7 and 429.7 keV line this is confirmed by their identification (see below) with crossover transitions in a $\Delta I = 1$ cascade. The angular distribution of some of the γ rays assigned to ^{78}Rb are shown in Fig. 3.

V. THE LEVEL SCHEME AND ITS ISOTOPIC IDENTIFICATION

The data in Tables I and II lead, rather unambiguously, to the level scheme shown in Fig. 4. The order of the transitions is determined by their relative intensities and, in some cases, by the observation of crossover transitions. The energy agreement obtained between the latter and the cascades is quite satisfactory. Also, the identification of these crossover transitions reinforces the spin assignments deduced from the angular distribution data. The stronger lines show a negative anisotropy, thus indicating $\Delta I = 1$ char-

TABLE II. Energies, intensities, angular distribution coefficients, and anisotropies of γ rays assigned to the $^{64}Zn(^{16}O,np)^{78}Rb$ reaction. Errors in the least significant figure are indicated as superscripts.

E_γ (±0.2) (keV)	Intensity[a] (44 MeV)	Intensity[a] (52 MeV)	A_2 (52 MeV[c])	A_4 (52 MeV[c])	Anisotropy[b] (44 MeV)
152.6	0.82^8	0.84^6	-0.53^1	0.01^1	-0.5^2 (152.6 and 155.2)
155.2	0.62^6	0.57^5	-0.47^1	0.01^1	
185.6	0.14^2	0.16^2	-0.49^3	0.05^3	-0.2^1
225.0	0.20^2	0.16^2	-0.64^3	0.03^1	-0.5^3
244.4	0.24^3	0.22^2	-0.51^3	-0.03^1	-0.3^2
278.5[d]	(0.19^3)	(0.18^3)			···
307.7	0.08^2	0.06^1	0.26^5	0.05^6	0.6^3
366.8	0.09^2	0.10^2	-0.65^2	0.05^3	···
377.6[e]	0.09^3	0.10^2	···	···	···
397.5	0.08^3	0.07^2	···	···	1.2^6
405.7	···	0.05^2	-0.6^2	-0.4^2	···
429.7	0.07^3	0.11^2	0.42^4	-0.11^5	1.5^7

[a] Intensities are normalized so that the total intensity into the lowest state (Fig. 4) is equal to unity.

[b] $W(0°)/W(90°) - 1$.

[c] Only statistical errors are quoted.

[d] Coincidence measurements indicate that only 25% of the 278.5 keV peak intensity belongs to ^{78}Rb if the proposed level scheme (Fig. 4) is correct.

[e] The given intensity corresponds to 60% of total peak area. Remaining intensity belongs to ^{77}Kr.

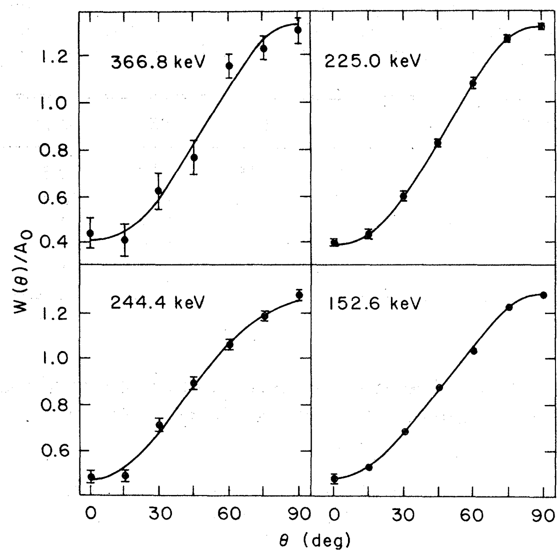

FIG. 3. Angular distributions of some γ rays of ^{78}Rb. The fits to the data were obtained including the 120° data point.

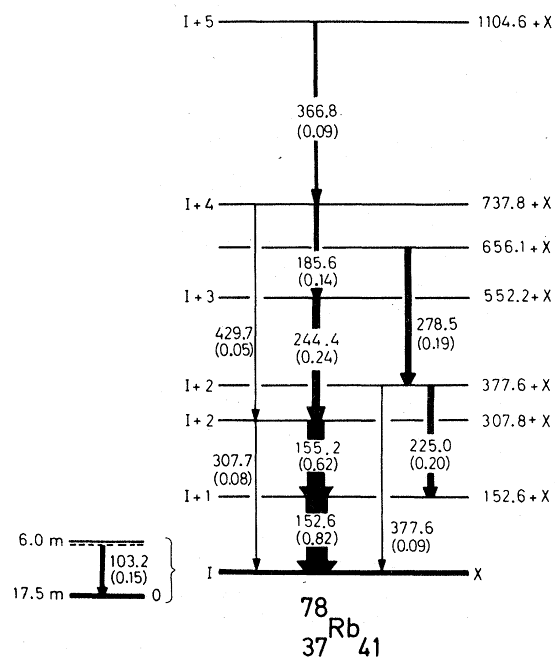

FIG. 4. Proposed level scheme for ^{78}Rb. It is not known which of the two previously known isomers in ^{78}Rb (indicated on the left) correspond to the lowest state I, but most probably it is the 6 min isomer.

acter. The increasing spin sequence is chosen because of lack of high energy crossover transitions.

The assignment of this level scheme to the ^{78}Rb isotope is mainly based on the determination of relative cross sections and balance between prompt and decay intensities. These measurements involved collecting on- and off-beam data along a controlled time scale.

A brief discussion on each of the different possible reaction channels follows. We shall limit ourselves to reactions involving two and three particles since others should have a negligible contribution at 44 MeV, the energy at which these measurements were carried out. Intensity values will be given relative to the total (prompt) intensity observed to populate the lowest state in Fig. 4.

$(^{16}O, 2n)^{78}Sr$. The only available information on this nucleus is the 30.6 min half-life of its decay to ^{78}Rb (Ref. 14). We can only deduce that the cross section for this reaction is negligible as no influence of the longer half-life on the $^{78}Rb \rightarrow {}^{78}Kr$ decay is observed. This result is in agreement with the analysis of the systematics mentioned earlier; while $\delta(^{64}Zn) = 6.2$, the $(^{16}O, 2n)$ reaction at 44 MeV becomes important for targets with $\delta < 5.5$, such as ^{63}Cu and ^{66}Zn, it is very weak for ^{60}Ni ($\delta = 5.8$) and has not been observed for ^{58}Ni ($\delta = 7$).

Further, the level scheme of Fig. 4 cannot be identified with what one expects for an even-even nucleus, such as ^{78}Sr.

$(^{16}O, np)^{78}Rb$. On the basis of the results of Nolte and Shida,[3] our study of the 6 min decay yields a cross section of σ_{np} (6 min) $= 1.45 \pm 0.20$ (relative to the total intensity populating the lowest state in Fig. 4). About 10% of this value corresponds to the 103.2 keV transition branch which feeds the 17.5 min ground state of ^{78}Rb. The 17.5 min decay (after subtracting the contribution of the 6 min decay through the 103.2 keV line) yields a cross section of σ_{np}(17.5 min) $= 0.6 \pm 0.2$. These cross sections were obtained by assuming negligible direct feeding into the ^{78}Kr ground state, in accordance with the results reported in Ref. 3. The level scheme of Fig. 4 gives a satisfactory intensity balance with the 6 min decay cross section. However, owing to the errors involved, the possibility that the prompt transitions in Fig. 4 populate the 17.5 min isomer must be taken into consideration. We shall come back to this point later.

$(^{16}O, 2p)^{78}Kr$. The level scheme of ^{78}Kr is well known from previous studies.[3,8] The cross section for this reaction, using the known ground state band transitions, has been estimated to be σ_{2p}

$= 1.3 \pm 0.1$.

$(^{16}O, n\alpha)^{75}Kr$. We do not have information on states of ^{75}Kr, but the 4.5 min decay to levels of ^{75}Br has been studied by Roeckel *et al.*[9] From their data and the intensity of the 132.5 keV γ ray in our decay spectra, a cross section $\sigma_{n\alpha} = 0.08 \pm 0.02$ is obtained. This value is based on the reasonable assumption that the $(^{16}O, 4np)$ reaction to levels of ^{75}Rb is negligible. This small cross section value allows us to conclude that the level scheme of Fig. 4 does not correspond to ^{75}Kr.

$(^{16}O, p\alpha)^{75}Br$. The level scheme of ^{75}Br has been studied both from the radiactive decay of ^{75}Kr (Ref. 9) and from the $^{75}As(\alpha, 4n)$ reaction.[11] An average cross section of $\sigma_{p\alpha} = 0.6 \pm 0.2$ is obtained from the prompt intensity of the 132.5 keV transition and from the measured intensity of the 286.6 keV line produced in the 95 min $^{75}Br \rightarrow {}^{75}Se$ decay.[12]

$(^{16}O, 3n)^{77}Sr$. This reaction is expected to be even weaker than the $(^{16}O, 2n)$ reaction. An upper limit of $\sigma_{3n} < 0.02$ is deduced from the same limit for the $^{77}Rb \rightarrow {}^{77}Kr$ decay (see below) by making the reasonable assumption that the half-life of the $^{77}Sr \rightarrow {}^{77}Rb$ decay is not longer than a few minutes.

$(^{16}O, 2np)^{77}Rb$. The strong 66.6 keV line in the 3.9 min decay[13] to ^{77}Kr is not seen in the off-beam spectra. The intensity of the direct decay into the $\frac{5}{2}^+$ ^{77}Kr ground state is not known. The ground state spins and parities of the odd-A, $N = 40$ isotones and of the heavier odd-A Rb isotopes suggest a $\frac{3}{2}^-$ or $\frac{5}{2}^-$ assignment for the ground state of ^{77}Rb. The fact that the $\frac{3}{2}^-$ and $\frac{5}{2}^-$ states of ^{77}Kr at 66.6 and 245.4 keV are strongly populated in the decay supports this conjecture. On this basis it is reasonable to expect that the direct decay into the ground state of ^{77}Kr is weaker than to these negative parity states. Even allowing for a direct ground state feeding equal to that of the 66.6 keV level a limit of $\sigma_{2np} < 0.02$ is obtained.

$(^{16}O, n2p)^{77}Kr$ and $(^{16}O, 3p)^{77}Br$. The level scheme of ^{77}Kr has been studied by Nolte *et al.*[2] and the main γ-ray transitions in this nucleus are clearly seen in the present work. An estimate of $\sigma_{n2p} = 0.8 \pm 0.3$ for the relative cross section of the $(^{16}O, n2p)$ reaction is obtained, where the large error stems from the uncertainty[2] in the intensity of the 66.6 keV transition.

Until now, only γ rays of ^{77}Br produced in the decay of ^{77}Kr have been observed. If the direct ground state feeding in this decay is neglected (see Ref. 10), a total decay intensity of 0.5 ± 0.1 is determined on the basis of the 129.7 and 146.6 keV peak areas. However, the result[10] that the direct decay into the ground state is less than 1% of the total is based on the assumption that the ground state of ^{77}Kr has spin-parity $I^\pi = \frac{7}{2}^+$, an assignment which is in disagreement with the more recently proposed[2] value $I^\pi = \frac{5}{2}^+$ for this state. If this newer assignment is adopted and the smallest $\log ft$ value consistent with the systematics of first forbidden transitions[15] is assumed, that is, $\log ft = 6$, a maximum contribution of 16% for the decay into the ground state is obtained. In this case the $^{77}Kr \rightarrow {}^{77}Br$ decay is seen with a total intensity of 0.60 ± 0.15. This value, when compared to $\sigma_{n2p} = 0.8 \pm 0.3$ as given above, suggests a vanishing amount of prompt intensity from the $(^{16}O, 3p)$ reaction inasmuch as this reaction adds intensity to the 129.7 and 146.6 keV γ lines. The $\frac{9}{2}^+$ to g.s. 106 keV transition, on the other hand, is not observed. However, owing to the errors involved we can only set the limit $\sigma_{3p} < 0.25$.

$(^{16}O, 2n\alpha)^{74}Kr$. The lowest ground state band transitions in ^{74}Kr have been reported by Nolte *et al.*[16] The 2^+ state lies at 455.7 ± 0.4 keV so that the corresponding γ peak may not be resolved from the strong 454.9 keV line of ^{78}Kr. We therefore establish a maximum cross section of $\sigma_{2n} < 0.02$ for this reaction on the basis of the largest intensity value, compatible with our data, for the 557.8 keV, $4^+ \rightarrow 2^+$ transition[16] in ^{74}Kr. A similar limit is obtained from an estimate of the maximum intensity of the strongest 89.7 keV transition in the $^{74}Kr \rightarrow {}^{74}Br$ decay[17] [see Fig. 1(c)].

$(^{16}O, np\alpha)^{74}Br$ and $(^{16}O, 2p\alpha)^{74}Se$. Only preliminary data from a (HI, xn) type reaction leading to states of ^{74}Br are available.[18] We do not see the γ rays of 188.4, 195.0, and 383.5 keV tentatively assigned to this nucleus.[18] We can set a limit of $\sigma_{np\alpha} < 0.03$ based on the nonobservation of the strong 634.8 keV line from the 25.3 and 41.5 min $^{74}Br \rightarrow {}^{74}Se$ decays.[19,20] Likewise the nonobservation of this transition in the prompt spectrum allows us to determine that the cross section for the $(^{16}O, 2p\alpha)$ reaction is smaller than $\sigma_{2p\alpha} < 0.02$. A summary of the cross section values given above is presented in Table III.

From this analysis it is concluded that the level scheme of Fig. 4 corresponds to the ^{78}Rb isotope, since: (a) The intensity balance between the observed prompt intensity and the $^{78}Rb \rightarrow {}^{78}Kr$ decay is satisfactory. (b) There is no other γ ray or groups of γ rays in the prompt spectrum with enough intensity to provide an explanation for the strong $^{78}Rb \rightarrow {}^{78}Kr$ decay as observed in the off-beam mode. (c) It is consistent with the expectation that the $^{64}Zn(^{16}O, np)$ and $^{64}Zn(^{16}O, 2p)$ reactions should dominate the total cross section, and the fact that the latter is clearly observed with the expected strength.

As mentioned above, the present results favor the identification of the lowest state I in Fig. 4

TABLE III. Summary of relative partial cross sections from the ^{64}Zn + 44 MeV ^{16}O reaction. The values are normalized to the total prompt intensity seen to populate the lowest state in the level scheme proposed for ^{78}Rb (Fig. 4).

No. of outgoing particles	Outgoing particles	Product nucleus	Relative partial cross section
2	$2n$	^{78}Sr	small
	np	^{78}Rb	2.05 ± 0.30 [a]
	$2p$	^{78}Kr	1.3 ± 0.1
	$n\alpha$	^{75}Kr	0.08 ± 0.02
	$p\alpha$	^{75}Br	0.6 ± 0.2
3	$3n$	^{77}Sr	<0.02
	$2np$	^{77}Rb	<0.02
	$n2p$	^{77}Kr	0.8 ± 0.3
	$3p$	^{77}Br	<0.25
	$2n\alpha$	^{74}Kr	<0.02
	$np\alpha$	^{74}Br	<0.03
	$2p\alpha$	^{74}Se	<0.02

[a] Total of σ_{np} (6 min) = 1.45 ± 0.20 plus σ_{np} (17.5 min) = 0.6 ± 0.2. The first value is based on the assumption that the 103.2 keV transition is dipolar, and the latter value is obtained by assuming that the 103.2 keV transition provides the only path connecting both isomers.

with the 6 min isomer of ^{78}Rb, although the accuracy is not enough to allow us to readily rule out the possibility that such state corresponds, instead, to the 17.5 min ground state of ^{78}Rb.

In the calculation of the cross section σ_{np} (6 min) = 1.45 ± 0.20, we have assumed that the 103.2 keV transition is dipolar (hence adding only 10% to its total intensity from internal conversion) because an octupole transition feeding the 17.5 min ground state, such as required by the half-life of the isomer, would lead to contradiction with the total intensity seen to depopulate the ground state. However, the available data up to now do not permit us to rule out entirely quadrupole character for this transition. If such were the case a new smaller value for σ_{np} (17.5 min) would result, lending further support to the hypothesis that the 6 min isomer is the head of the band structure shown in Fig. 4.

It could also be that the actual σ_{np} (17.5 min) cross section is smaller than the measured value if there were an unobserved branch from the 6 min isomer to the ground state, parallel to the 103.2 keV transition.

In synthesis, while conclusive evidence is lacking, it appears much more likely that the present level scheme is built on the 6 min high spin isomer of ^{78}Rb, rather than on the 17.5 min ground state.[21]

VI. CONCLUSIONS

In this work a level scheme for ^{78}Rb is proposed for the first time. The main part of the level scheme has the structure of a $\Delta I = 1$ band built most probably on the previously discovered 6 min isomer. From the decay of this isomer into levels of ^{78}Kr, it has been suggested that its parity is[3] negative and its spin is probably $I = 4 \pm 1$. Thus, as expected, high spin states up to $I = 8$ or more may have been reached.

As stated in the Introduction, the main motivation for this investigation was to learn more about the hitherto noted[1] parallelism between the structures of ^{76}Br and ^{77}Kr. It was then thought that the same features could also be found in ^{78}Rb. The present results appear to confirm such a suspicion, thus adding interest to the problem of understanding the nature of these bands. In the earlier work[1] on ^{76}Br the band head was identified with the 1^- ground state. However, it has been recently suggested[22] that the band head should probably correspond to an unknown higher spin state near the ground state as the band is not seen either from the ^{76}Kr decay or from the $(p, n\gamma)$ reaction. In view of the present results such a possibility would reinforce the similarity with ^{78}Rb. A comparison of the level energies of the three isotones ^{76}Br, ^{77}Kr, and ^{78}Rb is presented in Fig. 5. Only the levels of the main bands found in the doubly odd nuclei and the ground state band[2] of ^{77}Kr are drawn. The parallelism between the excitation energies of the two doubly odd isotones is apparent, and it is also verified for the first two excited states of ^{77}Kr, but the similarity of the level staggering in the three nuclei appears to be even more interesting and it is probably more

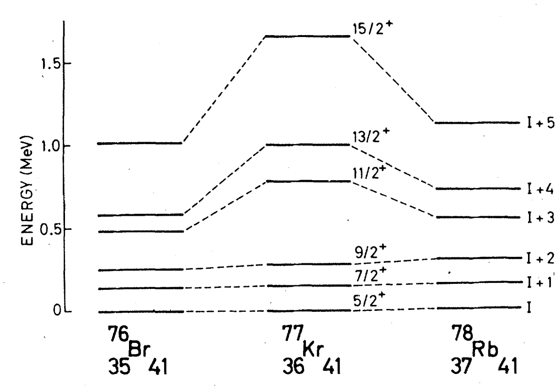

FIG. 5. The main band found in ^{78}Rb is compared to that in ^{76}Br (Ref. 1) and the $\frac{5}{2}^+$ ground state band of ^{77}Kr (Ref. 2). The similarities in the excitation energies of the first two excited states as well as in the level staggering exhibited by the three nuclei are apparent.

significant. It points to the possibility that a close relationship exists between the excitation mechanisms of the odd A and doubly odd systems.

Doubly odd nuclei are generally regarded as systems with relatively complicated structures owing to the dominant p-n interaction. The results discussed here may indicate that this is not always the case; simple systematic features may emerge such as those found in this work which stimulate further experimental as well as theoretical investigations. An interesting immediate problem which remains open is the determination of the spin and parity of the band heads in both ^{76}Br and ^{78}Rb.

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