High-spin states in ^{79}Kr populated by the ^{78}Se(α,3n) reaction and interpreted in terms of a quasiparticle-plus-rotor model

M. Behar, A. Filevich, and A. O. Macchiavelli
Departamento de Física, Comisión Nacional de Energía Atómica, 1429 Buenos Aires, Argentina

L. Szybisz
Consejo Nacional de Investigaciones Cientificas y Técnicas and Departamento de Física, Facultad de Ciencias Exactas, Universidad Nacional de La Plata, 1900 La Plata, Argentina

P. Thieberger
Department of Physics, Brookhaven National Laboratory, Upton, New York 11973
(Received 25 February 1982)

Nuclear states of ^{79}Kr were studied through the ^{78}Se(α,3n) reaction at an energy of 45 MeV. Excitation functions, γ-ray angular distributions, and γ-γ coincidences were performed. Three bands based on the g.s. ($1/2^-$), 147.1 keV ($5/2^-$), and 129.7 keV ($7/2^+$) states were identified. Leading order analysis and quasiparticle-plus-rotor model calculations were performed. A good overall agreement was found between the experimental data and the theoretical predictions.

[NUCLEAR REACTIONS ^{78}Se(α,3n), E=30−55 MeV; measured $\sigma(E,E_\gamma,\theta)$, E_γ, I_γ, γ-γ coin. ^{79}Kr deduced levels J. Enriched targets.]

I. INTRODUCTION

Evidence for the existence of deformed nuclei in the neutron deficient region $A=70-80$, $31\leq Z\leq 37$, was reported in the early seventies.[1] From a systematics of energy levels it is expected that $N\approx 42$ nuclei should exhibit sizable collective effects. Since the International Conference on Vibrational Nuclei that was held at Zagreb in 1974, a number of works have been devoted to the study of the characteristics of the rotational bands in such nuclei. A summary of the most recent publications on this matter can be found in Ref. 2.

In the case of the odd-neutron isotopes, thorough investigations of high-spin states in ^{73}Se (Refs. 3 and 4), ^{75}Se (Refs. 5 and 6), ^{77}Se (Ref. 7), ^{79}Se (Ref. 8), and ^{77}Kr (Ref. 9) have been performed through (α,xn) and heavy ion induced reactions. Although ^{79}Kr, with N=43, becomes an important test case, no further complete work on high spin states in this isotope has been published since the preliminary results reported by the Stockholm group.[10–13] In the most recent literature, there are contributions dealing with some specific aspects of the structure of ^{79}Kr. Thus, Bharathi *et al.*[14] and Chao *et al.*[15] have measured several spectroscopic factors using the (p,n) and (d,p) stripping reactions, respectively. Lipták and Krištiak[16] have populated low-spin states through the β^+-EC decay of ^{79}Rb, and Clements *et al.*[17] have analyzed the sequence of some positive parity levels by means of the ^{72}Ge(^{10}B,2np) reaction. Several questions should still be clarified and, in particular, the results for the negative bands remain "tentative." To obtain more information we studied the ^{79}Kr isotope through the ^{78}Se(α,3n) reaction.

II. EXPERIMENTAL PROCEDURE

A. Experimental setup

A 55 MeV alpha beam was obtained from the Buenos Aires synchrocyclotron and was degraded to energies between 30 and 50 MeV. The target was made of 97.2% enriched ^{78}Se. Its area was about 4 mm^2 and the thickness was 5 mg/cm^2.

The gamma radiation was detected with two

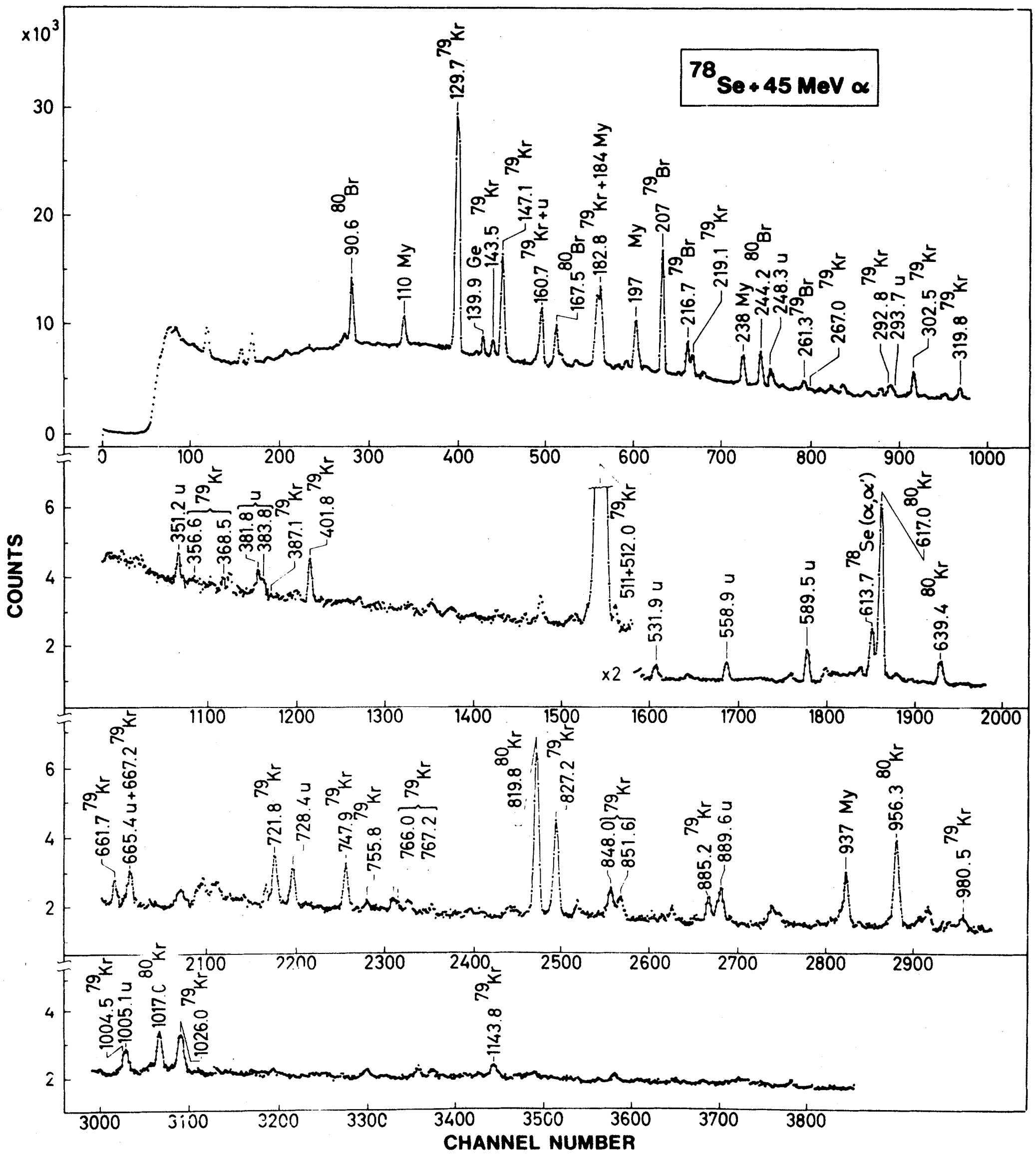

FIG. 1. Single γ-ray spectra obtained following the ^{78}Se + 45 MeV reaction. *U* stands for unidentified lines, while *M* labels peaks originated in the Mylar target holder.

coaxial Ge(Li) detectors of 10% and 15% efficiency and 2.3 keV resolution, respectively. A small Ge(Li) x-ray detector with 700 eV resolution at 122 keV was also used.

The analysis of the gamma spectra was performed with the help of standard computer techniques. Sources of ^{152}Eu, ^{133}Ba, and ^{241}Am were used for energy and efficiency calibration of the Ge(Li) and x-ray detectors in the experimental geometry.

B. Experimental results

A single gamma-ray spectrum taken at $E_\alpha = 45$ MeV is shown in Fig. 1. In addition to the lines which belong to ^{79}Kr, other prominent gamma rays were produced in reactions like (α,*np*), (α,2*n*), and (α,2*np*). Several unidentified lines could deexcite levels of ^{79}Br which—to our knowledge—have not been studied through (HI,*xn*) reactions.

The isotopic assignment was done on the follow-

TABLE I. Summary of the results of the present experiment at E=45 MeV.

E^a	I	$I_i - I_f$	A_2	A_4	α_2	$\alpha_4{}^d$	
129.7	80 ±10	$\frac{7}{2}^+ - \frac{1}{2}^-$					$E2$
143.5	7.5± 1.0	$\frac{5}{2}^+ - \frac{5}{2}^-$					
147.1	54 ± 5	$\frac{5}{2}^- - \frac{1}{2}^-$					$E2$
160.7	4.5± 1.0	$\frac{5}{2}^+ - \frac{7}{2}^+$					
182.8	23 ± 2	$\frac{3}{2}^- - \frac{1}{2}^-$	−0.20±0.02	0.01±0.03	0.46±0.05[b]		$-0.02 \leq \delta \leq 0.08$
219.1	8 ± 1	$\frac{5}{2}^- - \frac{3}{2}^-$	−0.22±0.04	−0.03±0.05	0.56±0.06[b]		$-0.04 \leq \delta \leq 0.04$
267.0	1.3± 0.5	$\frac{7}{2}^- - \frac{3}{2}^-$					$E2$
292.8	4 ± 1	$\frac{7}{2}^- - \frac{5}{2}^-$	−0.29±0.06	−0.05±0.07	0.66±0.11[b]		$-0.01 \leq \delta \leq 0.04$
302.5	19 ± 2	$\frac{7}{2}^- - \frac{5}{2}^-$	0.35±0.05	0.03±0.07	0.40±0.10[b]		$0.5 \leq \delta \leq 4$
319.8	8 ± 2	$\frac{7}{2}^- - \frac{7}{2}^+$	0.19±0.06	0.04±0.07	0.40±0.10[b]		$-0.2 \leq \delta \leq 0.2$
356.6	1.1± 0.5	$\frac{11}{2}^- - \frac{9}{2}^-$					
368.5	2.0± 0.4	$\frac{9}{2}^- - \frac{7}{2}^-$					
387.1	0.9± 0.5	$\frac{11}{2}^- - \frac{9}{2}^-$					
401.8	11 ± 1	$\frac{5}{2}^- - \frac{1}{2}^-$	0.32±0.03	−0.08±0.04	0.56±0.06	0.14±0.07	$E2$
512.0[c]	8.0± 2.5	$\frac{7}{2}^- - \frac{3}{2}^-$					$E2$
661.7	10 ± 1	$\frac{9}{2}^- - \frac{5}{2}^-$	0.36±0.05	−0.10±0.06	0.76±0.11	0.35±0.20	$E2$
667.2	16 ± 2	$\frac{9}{2}^- - \frac{5}{2}^-$	0.25±0.03	−0.05±0.04	0.52±0.06	0.17±0.15	$E2$
721.8	26 ± 3	$\frac{11}{2}^- - \frac{7}{2}^-$	0.27±0.03	−0.07±0.05	0.60±0.05	0.30±0.20	$E2$
747.9	18 ± 2	$\frac{11}{2}^+ - \frac{9}{2}^+$	−0.19±0.03	−0.02±0.05	0.55±0.05[b]		$-0.02 \leq \delta \leq 0.04$
755.8	6 ± 1	$\frac{11}{2}^- - \frac{7}{2}^-$	0.36±0.07	−0.10±0.08	0.82±0.16	0.47±0.40	$E2$
766.0	7 ± 2	$\frac{15}{2}^+ - \frac{11}{2}^+$	0.30±0.06	−0.10±0.07	0.72±0.20	0.40±0.32	$E2$
767.2	2 ± 1	$\frac{11}{2}^+ - \frac{7}{2}^+$					
827.2	70 ± 7	$\frac{13}{2}^+ - \frac{9}{2}^+$	0.30±0.04	−0.08±0.04	0.67±0.10	0.37±0.18	$E2$
848.0	13 ± 2	$\frac{13}{2}^- - \frac{9}{2}^-$	0.29±0.04	−0.08±0.05	0.66±0.05	0.21±0.13	$E2$
851.6	8 ± 3	$\frac{13}{2}^- - \frac{9}{2}^-$	0.38±0.08	−0.08±0.10	0.86±0.20		$E2$
885.2	17 ± 3	$\frac{15}{2}^- - \frac{11}{2}^-$	0.34±0.03	−0.07±0.04	0.79±0.10	0.35±0.20	$E2$
980.5	8 ± 2	$\frac{17}{2}^- - \frac{13}{2}^-$	0.35±0.05	−0.08±0.07	0.83±0.15	0.44±0.38	$E2$
1004.5	7 ± 3	$\frac{19}{2}^- - \frac{15}{2}^-$	0.38±0.10	−0.05±0.12	0.92±0.23		$E2$
1026.0	35 ± 4	$\frac{17}{2}^+ - \frac{13}{2}^+$	0.32±0.05	−0.09±0.05	0.76±0.15	0.50±0.25	$E2$
1143.8	9 ± 2	$\frac{21}{2}^+ - \frac{17}{2}^+$	0.37±0.06	−0.10±0.07	0.91±0.20	0.60±0.40	$E2$

[a]Typical energy errors are of 0.3 keV.
[b]Values deduced from those determined in the corresponding band.
[c]Intensity estimated from the coincidence experiment.
[d]All listed α_4 values have been obtained from the experimental nonzero A_4 coefficients. They are included in order to show the consistency with the corresponding α_2 values.

ing basis. From β^+-EC decay of ^{79}Rb the 19.1, 129.7, 143.5, 147.1, 160.7, 182.8, 219.1, 302.5, 319.8, and 401.8 keV gamma rays are known to belong to ^{79}Kr (Ref. 16). Similarity of excitation functions and coincidences with these transitions allow us to identify the lines which belong to the decay scheme of ^{79}Kr. Thus in addition to the above mentioned gamma rays, the lines at 267.0, 292.8, 356.6, 368.5, 387.1, 512.0, 661.7, 667.2, 721.8, 747.9, 755.8, 766.0, 767.2, 827.2, 848.0, 851.6, 885.2, 980.5, 1004.5, 1026.0, and 1143.8 keV were assigned as transitions in ^{79}Kr. The energies and in-

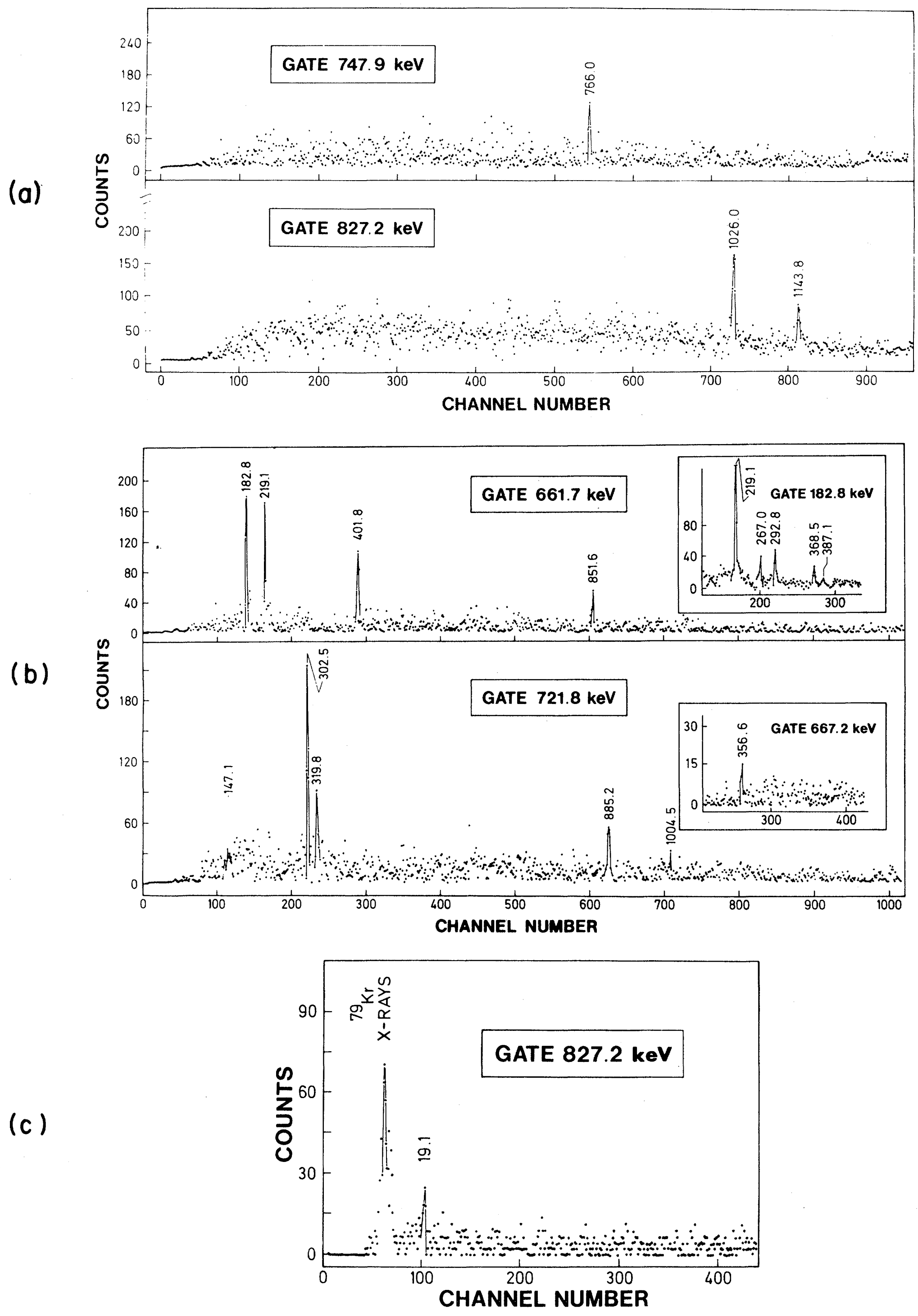

FIG. 2. Gamma-gamma coincidence spectra obtained at $E_\gamma = 45$ MeV. (a) Spectra gated with the 747.9 and 827.2 keV transitions. (b) Spectra gated with the 661.7 and 721.8 keV transitions. The insets show evidence for the coincidence of the 267.0, 368.9, and 387.1 and the 356.6 keV rays with the 182.8 and 667.2 keV lines, respectively. The intensity of the 147.1 keV peak in the 721.8 gated spectrum is small due to the lifetime of the level and the poor coincidence efficiency at this energy. (c) Spectrum gated by the 827.2 keV transition showing the coincidence with the 19.1 keV line.

TABLE II. Gamma-gamma coincidence results obtained at $E_\alpha = 45$ MeV. Energies are given in keV. The letter W denotes weak intensity. The measurements were carried out with both detectors at 90° with respect to the beam direction.

Gate \ E_γ	143.5	147.1	182.8	219.1	267.0	292.8	302.5	319.8	356.6	368.5	387.1	401.8	512.0	661.7
147.1	10±4						22±4							
182.8				80±10	4±2	17±4				10±4	W		70±20	50±10
219.1			70±10			30±10				10±4	W			50±15
292.8			16±4	20±3						W		25±3		
302.5		25±8												
401.8						20±3								45±10
661.7			36±5	32±5								40±6		
667.2		30±10							W					
721.8		W					140±20	66±10						
747.9														
755.8			35±5	8±2		19±6						7±3	30±10	
766.0														
827.2														
848.0		W												
851.6			30±10	60±20						W		35±10		76±20
885.2							60±10	25±5	W					
1004.5							26±15	W						
1026.0														

Gate \ E_γ	667.2	721.8	747.9	755.8	766.0	767.2	827.2	848.0	851.6	885.2	980.5	1004.5	1026.0	1143.8
147.1	15±4	W						W		W	W	W		
182.8				40±10					30±10					
219.1				10±2					35±10					
292.8				20±5										
302.5		140±20								100±20		40±20		
401.8				10±3					35±6					
661.7									60±15					
667.2								140±30			90±40			
721.8										180±20		50±20		
747.9					100±30									
755.8														
766.0			70±30			W								
827.2													300±50	150±30
848.0	130±30										90±20			
851.6														
885.2		110±20										W		
1004.5		40±20								40±20				
1026.0							415±50							110±30

tensities are given in Table I.

Two runs of gamma-gamma coincidence experiments were carried out. In the first one, the two Ge(Li) detectors were used as spectrometers. In the second one, a combination of a Ge(Li) and an x-ray detector was used in order to search for the gamma rays which are in coincidence with the 19.1 keV line. In both experiments the detectors were placed at 90° to the direction of the beam. Coincidences were recorded on magnetic tape for subsequent offline sorting. Examples of gated spectra are shown in Fig. 2, and the coincidence data are summarized in Table II. The numbers represent the peak areas corrected for the efficiency of both detectors.

Four runs of angular distribution measurements were performed by recording spectra at different angles from 25° to 155° with respect to the beam direction. A rotatable Ge(Li) detector was placed at 12 cm from the target. To normalize the spectra taken at different angles, the isotropic angular distribution of the 129.7 keV line deexciting the 50 sec isomeric level in ^{79}Kr was used. The normalized peak areas were fitted to the usual angular correlation function

$$W(\theta)=A_0[1+A_2P_2(\cos\theta)+A_4P_4(\cos\theta)] .$$

Whenever the A_4 coefficient obtained was consistent with zero, a second fit was carried out with only two free parameters A_0 and A_2. The resulting angular distribution coefficients are given in Table I. They are related to the tabulated[18] coefficients $A_K^{\max}$, which correspond to total alignment, by the attenuation coefficients α_K. For pure multipole transitions, the α_K coefficients can be obtained by comparing the experimental A_K with the tabulated $A_K^{\max}$ (Ref. 18). Then, they can be used to determine the mixing ratios for nonpure transitions.

Although the gamma ray angular distribution measurements were performed in order to determine the spins of the levels, the 1143.8 keV gamma ray had a small but measurable variation of the centroid, allowing lifetime measurements by the Doppler-shift attenuation method.

Observations were made at angles of 25°, 60°, 70°, 90°, 110°, 130°, and 155°. The centroid for the different angles was plotted as a function of $d+b\cos\theta$, where d represents the energy at 90° and b represents the attenuated Doppler shift. The experimental attenuation coefficient $F(\tau)$ is the ratio of b to the kinematic full shift. The obtained value was $F(\tau)=0.18\pm0.04$. In order to convert the $F(\tau)$ value into lifetime we have used the formalism of

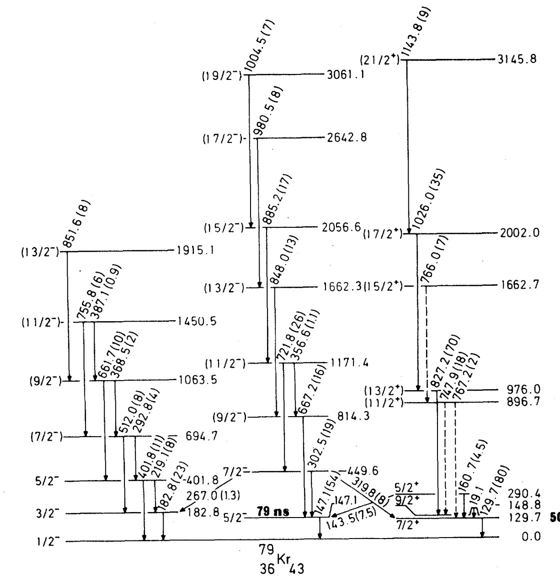

FIG. 3. Level scheme for ^{79}Kr proposed as a result of this present work.

Blaugrund[19] based on the theory of atomic collisions of Lindhard, Scharff, and Schiott.[20] However, since some of the parameters involved could barely be estimated, we can extract only a lifetime limit for this transition that is $\tau \geq 1.5$ psec.

III. ENERGY LEVELS AND DECAY SCHEME

The ^{79}Kr level scheme shown in Fig. 3 was constructed on the basis of gamma ray intensity balance, gamma-gamma coincidences, energy relationship, and gamma-ray angular distributions. The ground state of ^{79}Kr is known to be $\frac{1}{2}^-$.[14,15,21] The 182.8 and 401.8 keV levels have been populated in the β^+-EC work of Lipták and Krištiak and spin parities $\frac{3}{2}^-$ and $\frac{5}{2}^-$ were respectively assigned in agreement with the (p,n) work of Bharathi *et al.*[14] The results of our angular distribution measurements of the 182.8 and 219.1 keV transitions (consistent with $\Delta I=1$), and of the 401.8 keV gamma ray (typical of a stretched quadrupole transition) are in agreement with these previous assignments.

The 661.7 and 851.6 keV angular distribution results correspond to stretched quadrupole transitions; we then propose for the 1063.5 and 1915.1 keV levels spin parities $\frac{9}{2}^-$ and $\frac{13}{2}^-$, respectively.

The 694.7 keV level decays, through the 512.0 and 292.8 keV gamma-ray transitions, to the 182.8 $I=\frac{3}{2}^-$ and the 401.8 $I=\frac{5}{2}^-$ keV levels. The 292.8

keV angular distribution result is characteristic of a $\Delta I=1$ transition, indicating that this level could have spin $\frac{3}{2}$ or $\frac{7}{2}$. However, the lack of a sizable ground state transition together with the fact that the 694.7 keV level is fed from the $I=\frac{9}{2}^-$ 1063.5 keV level through the 368.5 keV transition indicates that its most probable spin is $\frac{7}{2}$. Therefore, it is very likely that the 512.0 keV transition is a pure $E2$, and thus a negative parity is favored for the 694.7 keV level. Finally, since the 1450.5 keV level deexcites to the 694.7 keV level through the 755.8 stretched quadrupole transition, we propose $I=\frac{11}{2}^-$ for this state.

The 147.1 and 449.6 keV levels are known to have spin and parity $\frac{5}{2}^-$ and $\frac{7}{2}^-$, respectively.[16] The second one deexcites to the 147.1, 129.7, and 182.8 keV levels through the 302.5, 319.8, and 267.0 keV gamma rays. While the first two were reported previously in the literature,[14,16] the 267.0 keV transition was observed for the first time in this work. For the 302.5 keV gamma transition the positive A_2 indicate a quadrupole admixture, while for the 319.8 keV gamma ray the A_2 and A_4 coefficients are consistent with a $\Delta I=0$ transition.

The 667.2, 721.8, 848.0, and 980.5 keV gamma rays show angular distributions typical of stretched quadrupole transitions. Therefore, we propose spin parities $\frac{9}{2}^-$, $\frac{11}{2}^-$, $\frac{13}{2}^-$, $\frac{15}{2}^-$, and $\frac{17}{2}^-$ for the 814.3, 1171.4, 1662.3, 2056.6, and 2642.8 keV levels, respectively. The angular distribution result for the 1004.5 keV gamma ray ($A_2>0$ and A_4 consistent with zero) indicates a $\Delta I=0$, 1, or 2 transition. However, the lack of sizable transitions to other levels could indicate that in fact it is a $\Delta I=2$ transition, and therefore $\frac{19}{2}^-$ is the proposed spin parity for the 3061.1 keV level.

The 129.7, 148.8, and 290.4 keV levels are known to have spin and parity $\frac{7}{2}^+$, $\frac{9}{2}^+$, and $\frac{5}{2}^+$, respectively.[16] The decay mode of the 290.4 keV level is confirmed by the present data. Our coincidence experiment shows not only the existence of the previously observed[17] 827.2-, 1026.0- and 1143.8 keV gamma-ray cascade, but also that it is based on the 148.8 keV level. This fact is clearly shown by the coincidence between the 19.1 and 827.2 keV gamma rays [see Fig. 2(b)]. Each of the components of the cascade shows an angular distribution consistent with a stretched quadrupole transition; therefore, $\frac{13}{2}^+$, $\frac{17}{2}^+$, and $\frac{21}{2}^+$ are the most likely assignments for the 976.0, 2002.0, and 3145.8 keV levels.

In addition, there is a 766.0-747.9 keV gamma-ray cascade which is probably based on the 148.8 keV state. This assumption results from three facts:

(a) The existence of a 767.2 keV line. It is observed in singles and in a weak coincidence with the 766.0 keV line. Therefore it probably connects the 896.7 and 129.7 keV levels.

(b) The 747.9 keV line angular distribution has a negative A_2 value which is indicative of a $\Delta I=1$ transition. If this line is based on the 129.7 keV $\frac{7}{2}^+$ level, there would be a $\frac{5}{2}^+$ or $\frac{9}{2}^+$ state at an energy of 877.9 keV. The first possibility can be excluded on the basis of: (i) the absence of a line connecting this level with the $\frac{5}{2}^+$ state at 290.4 keV; and (ii) the lack of feeding from the β^+-EC decay of ^{79}Rb. The second possibility is also unlikely since there is no sizable transition to the $\frac{7}{2}^+$ 129.7 keV level.

(c) In the same region of the Periodic Table, ^{75}Se and ^{77}Se isotopes show the same feature for the positive parity band; that is, two lines feeding a $\frac{9}{2}^+$ state, one deexciting a $\frac{13}{2}^+$ level and the other deexciting the corresponding $\frac{11}{2}^+$ level. This systematics gives further support to the placement of the 747.9 keV line. Then, assuming that the 747.9 keV transition feeds the 148.8 state, its angular distribution indicates that the most likely spin assignment for the 896.7 keV level is $\frac{11}{2}$ (spin $\frac{7}{2}$ can be excluded, on the basis of the lack of transitions to the $\frac{9}{2}^+$ 129.7 keV and $\frac{5}{2}^+$ 290.4 keV levels). It is very difficult to determine univocally its parity. However, the absence of transitions to negative parity levels could indicate that it is a positive one. The 766.0 keV angular distribution is consistent with a stretched quadrupole transition, and therefore $\frac{15}{2}^+$ is proposed for the 1662.7 keV level.

The mixing ratio of the gamma ray transitions can be extracted from the corrected $A_K^{\max}$ angular distribution coefficients

$$\alpha_K = A_K / A_K^{\max} \ .$$

The corresponding results are quoted in Table I. As can be observed, the 182.8, 219.1, and 292.8 keV gamma rays show an almost pure $M1$ character. On the other hand, the angular distribution corresponding to the 302.5 keV transition gives a positive A_2, indicating the existence of an $E2$ admixture. Unfortunately this admixture is hard to determine and only limits between 10% and 90% can be established.

IV. DISCUSSION

The spin sequence, energy spacings, and decay properties of the three bands based on the g.s. ($\frac{1}{2}^-$), 147.1 keV ($\frac{5}{2}^-$), and 129.7 keV ($\frac{7}{2}^-$) states suggest

TABLE III. Rotational parameters of the best fit by Eq. (1) to negative bands in ^{79}Kr and ^{77}Se isotones and $K=0^+$ bands in the neighboring even-even ^{78}Kr and ^{80}Kr.

Nucleus	K	A (keV)	B (eV)	A_{2K} (keV)	B_{2K} (eV)	a	Set	Reference
^{79}Kr	$\frac{1}{2}^-$	51.5 ± 2.7	-252 ± 67	2.1 ± 4.1		0.04 ± 0.08	I	PW
		51.6	-279	8.2	-377	0.16	II	PW
	$\frac{5}{2}^-$	44.4 ± 2.5	-115				I	PW
		43.7	-105	-9.0×10^{-4}			II	PW
^{77}Se	$\frac{1}{2}^-$	56.7 ± 0.7	-272 ± 17	1.1 ± 4.0		0.02 ± 0.07		7
	$\frac{5}{2}^-$	51.5 ± 0.5	-201 ± 10					7
^{78}Kr	0^+	56.9	-188					PW
^{80}Kr	0^+	96.54	-767					23

a rotational interpretation. In what follows we analyze to which extent the observed properties correspond to a rotational pattern.

A. Test of leading-order description

The negative- and positive-parity bands are treated separately. Let us first discuss the features of the negative-parity states.

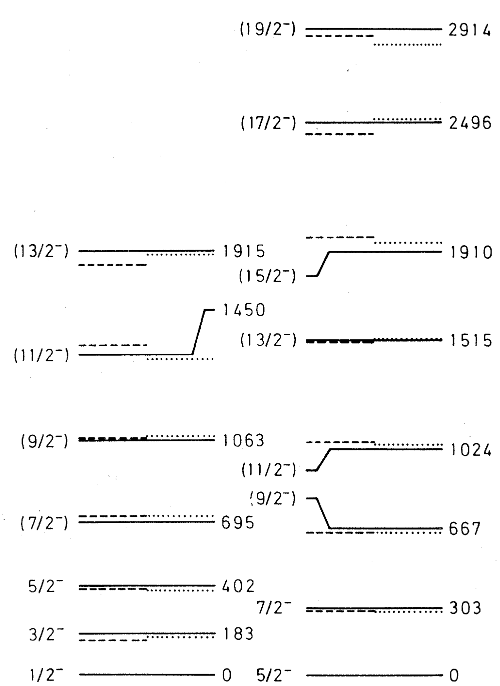

FIG. 4. Experimental energy sequences for both negative bands fitted by Eq. (1). Solid lines represent the experimental values, dashed and dotted lines show the fits with the set of parameters I and II, respectively (see text and Table III).

1. Negative-parity states

The rotational energy can be expressed as an expansion in powers of $I(I+1)$. To a good approximation a rotational spectrum obeys [i.e., see Eq. (4.62) in the book by Bohr and Mottelson[22]]

$$E_i = E_K + [A + BI(I+1)]I(I+1) + \cdots + \delta_{k>0}(-)^{I+K} \prod_{L=1-K}^{K} (I+L) \times [A_{2K} + B_{2K} I(I+1)] \,, \quad (1)$$

where K stands for the angular momentum of the bandhead, E_K fixes the energy of the bandhead, and $A=\hbar^2/2\mathscr{I}$ with $\mathscr{I}$ being the moment of inertia. The terms proportional to B, A_{2K}, and B_{2K} are higher order corrections to the leading-order term $AI(I+1)$ and $\sigma\equiv(-1)^{I+K}$ is the so-called signature. For $K=\frac{1}{2}$, $A_1=(\hbar^2/2\mathscr{I})a$, where a is the decoupling parameter.

The experimental energy sequences were fitted to Eq. (1). The parameters A and B were always considered free and two different choices were adopted for A_{2K} and B_{2K} for each negative band. The results for the parameters are listed in Table III and the energies are plotted in Fig. 4. The quality of the fit is satisfactory and no important difference was found between sets I and II for each band. The numerical values of the parameters obtained in the present work (PW) are almost equal to those derived by Zell *et al.*[7] in a study of similar negative bands in the isotone ^{77}Se. For the sake of a direct comparison the results of Ref. 7 are listed in Table III to-

TABLE IV. Branching ratios $[(g_K-g_R)/Q_0]^2$ and $|\delta|$ values for the negative parity bands of ^{79}Kr.

Band	I	$\sigma=(-1)^{I+1/2}$	λ PW	λ Ref. 16	$[(g_K-g_R)(1+\sigma b_0)/Q_0]^2$	$[(g_K-g_R)/Q_0]^2$	$\lvert\delta\rvert$ Calc.	$\lvert\delta\rvert$ Exp.
$K=\frac{1}{2}^-$	$\frac{3}{2}^-$	+1					0.22±0.09[a]	≤0.08
	$\frac{5}{2}^-$	−1	1.38±0.21	1.30±0.15	0.43±0.04[b]	0.47±0.06[c]	0.14±0.02	≤0.04
	$\frac{7}{2}^-$	+1	2.00±0.80		0.48±0.20	0.44±0.19[c]	0.12±0.04	0.04
	$\frac{9}{2}^-$	−1	5.0 ±1.1		0.37±0.08	0.41±0.10[c]		
	$\frac{11}{2}^-$	+1	6.7 ±3.3		0.49±0.29	0.45±0.27[c]		
$K=\frac{5}{2}^-$	$\frac{7}{2}^-$						≥2[d]	≤4
	$\frac{11}{2}^-$		24 ±11			0.000±0.002		

[a]This value was calculated using $[(g_K-g_R)(1+\sigma b_0)/Q_0]^2=0.48\pm0.20$.
[b]This value was derived from the average $\lambda=1.33\pm0.12$.
[c]These values were obtained using $b_0=0.048\pm0.061$.
[d]This value was estimated from the upper limit of $[(g_K-g_R)/Q_0]^2$ for this band.

gether with those corresponding to the neighboring even-even ^{78}Kr and ^{80}Kr.

The rotational parameter A is about 50 keV for both negative bands in the $N=43$ isotones ^{77}Se and ^{79}Kr. It agrees with the corresponding value for ^{78}Kr, but is smaller than the result for ^{80}Kr.

The very small staggering of the energies of levels differing by one unit of angular momentum in the $K=\frac{1}{2}^-$ bands in ^{77}Se and ^{79}Kr implies that these bands are associated with a negligible decoupling parameter a.

An additional test for the rotational picture is provided by the electromagnetic properties. In particular, meaningful information can be derived from ratios of gamma-ray intensities. From the measured relative gamma-ray intensities quoted in Table I several crossover-to-cascade branching ratios,

$$\lambda=T_\gamma(E2)/[T_{\gamma'}(M1)+T_{\gamma'}(E2)]\ ,$$

are determined. Here γ and γ' denote the crossover $I\rightarrow I-2$ and cascade $I\rightarrow I-1$ transitions, respectively. The results are listed in Table IV, where we also include the only previously known λ, which is in excellent agreement with our value.

According to the rotational model, using leading-order intensity relations, λ can be written in terms of a single combination of parameters

$$(g_K-g_R)(1+\delta_{K=1/2}\sigma b_0)/Q_0$$

(Ref. 24) with

$$\lambda=\left[\frac{E_\gamma}{E_{\gamma'}}\right]^5\frac{[(I+1)(I-1+K)(I-1-K)]/2K^2(2I-1)}{1+1.148[(g_K-g_R)(1+\delta_{K=1/2}\sigma b_0)/Q_0]^2(I+1)(I-1)E_{\gamma'}^{-2}}\ , \quad (2)$$

where g_K and g_R are the well-known g factors, b_0 is the magnetic decoupling parameter, and Q_0 is the intrinsic quadrupole moment. Here energies E_γ should be taken in MeV. From the tabulated branching ratios we single out the quantity $[(g_K-g_R)/Q_0]^2$. The results are listed in Table IV. In the case of the ground-state $K=\frac{1}{2}^-$ band the procedure is performed in three steps. First, the quantity

$$[(g_K-g_R)(1+\sigma b_0)/Q_0]^2$$

was calculated for each state; the corresponding results are also included in Table IV. Subsequently, assuming the constancy of $[(g_K-g_R)/Q_0]^2$, the four possible $(1-b_0)^2/(1+b_0)^2$ ratios are used to determine a weighted average $b_0=0.048\pm0.061$. Finally, using this result for b_0 the values $[(g_K-g_R)/Q_0]^2$ are obtained. Looking at Table IV, it can be seen that for the $K=\frac{1}{2}^-$ band this quantity is essentially constant, and the averaged value is $[(g_K-g_R)/Q_0]^2=0.45\pm0.05$. On the other hand, the information about the $K=\frac{5}{2}^-$ band is poorer, since only one value of $[(g_K-g_R)/Q_0]^2$ could be determined. This value is at most of order 10^{-3} and consistent with zero, indicating that the magnetic dipole radiation is strongly hindered for the cascade transitions within this band.

To derive further information about the g factors it is necessary to know the value of the intrinsic quadrupole moment Q_0, which unfortunately has not been measured yet. However, a tentative value of Q_0 can be obtained using the following equation [Eq. (16) of Ref. 25]:

$$Q_0=\frac{4}{5}ZR^2\delta_N(1+2/3\delta_N) \quad (3)$$

with $R=1.2\,A^{1/3}$ fm being the nuclear radius. The intrinsic quadrupole moment of the neighboring even-even Kr isotopes can be derived from the $B(E2)$ values of the $2^+\rightarrow 0^+$ transition. Under the assumption of axially symmetric deformation $\gamma=0°$ and using the experimental data quoted in Refs. 26 and 27, one obtains $Q_0=2.56\pm0.08$ and 1.91 ± 0.05 b for ^{78}Kr and ^{80}Kr, respectively. These values indicate a variation of the quadrupole deformation between both nuclei, as it was already suggested by the different moment of inertia mentioned above in this section. Assuming that the deformation parameter δ_N for ^{79}Kr is equal to that of the neighboring even-even nucleus with similar $\mathscr{I}$, one obtains $Q_0=2.75$ b and subsequently

$$|g_K-g_R|=1.84\pm0.10$$

and 0.03 ± 0.15 for the $K=\frac{1}{2}^-$ and $K=\frac{5}{2}^-$ bands, respectively.

For ^{79}Kr one knows the magnetic moment of the bandhead of the $K=\frac{5}{2}^-$ band, $\mu=1.12\pm0.01$.[28] In the rotational model, for $K=\Omega$, g_I obeys[22]

$$g_I=\mu/I=g_R+(g_K-g_R)K^2/I(I+1)\ . \quad (4)$$

Therefore, further information about g_K and g_R can be derived by combining data on $|g_K-g_R|$ and g_I, following the pioneering work of Boehm *et al.*[24] Owing to the uncertainty on the actual sign of δ the gyromagnetic factors g_K and g_R cannot be determined univocally. There are two sets of solutions for the $K=\frac{5}{2}^-$ band: set I, $g_K=0.46\pm0.19$ and $g_R=0.43\pm0.11$, and set II, $g_K=0.44\pm0.19$ and $g_R=0.47\pm0.11$. Both results for g_R are in agreement with the hydrodynamic approximation $g_R=Z/A=0.46$. Any of the phenomenological values of g_R in combination with $|g_K-g_R|=1.84\pm0.10$ results in $g_K=2.3\pm0.2$ or $g_K=-1.4\pm0.2$ for the $K=\frac{1}{2}^-$ band.

In Table IV the predicted and experimental $|\delta|$ values are also shown. As can be observed, the results for the $K=\frac{1}{2}^-$ band are in fairly good agreement, while the estimations for the $K=\frac{5}{2}^-$ band overlap each other.

Other interesting material to be analyzed is that related to the $|\Delta K|=2$ interband gamma transitions. The half-life, $T_{1/2}$, of the 147.1 keV gamma ray, which connects both bandheads, is known. Besides this 147.1 keV gamma ray, another interband transition of 267.0 keV was found, which involves the first excited states of these bands. No other interband transitions were observed. It is worthwhile to mention that also in the study of the isotone ^{77}Se, Zell *et al.*[7] only observed the interband $\frac{7}{2}^-$ $(K=\frac{5}{2}^-)\rightarrow\frac{3}{2}^-$ $(K=\frac{1}{2}^-)$ transition.

The weighted average of the available data on the $T_{1/2}$ of the 147.1 keV level [78 ± 6 nsec (Ref. 16), 77.7 ± 1.5 nsec (Ref. 28), 79.3 ± 1.5 nsec (Ref. 31), and 81.2 ± 3.2 nsec (Ref. 32)] is 78.7 ± 1.0 nsec. The corresponding $B(E2)$ value corrected by the internal conversion coefficient $\alpha_K=0.180\pm0.008$ (Ref. 15) is $(7.5\pm0.1)\times10^{-3}\,e^2$b^2, or 3.75 ± 0.05 W.u.

2. Positive-parity states

A fit of Eq. (1) to the positive-parity level sequence provides an unsatisfactory adjustment of the data. The pronounced staggering cannot be reproduced by Eq. (1). This fact is an indication that the positive band based on the $\frac{7}{2}^+$ state is strongly perturbed. The band is based on a single particle state which consists predominantly of the configuration $\frac{5}{2}^+$ [422] (originating in the $\nu g_{9/2}$ $m=\frac{5}{2}$ shell-model state). For such states the Coriolis matrix elements are so large that even for small angular momentum, perturbation theory is not applicable.

Bands with similar characteristics, where the $\frac{5}{2}^+$ state is pushed up above the $\frac{7}{2}^+$ and $\frac{9}{2}^+$ states and which exhibit a strong staggering, have been also found in the odd-neutron rare-earth nuclei. For instance, we can mention the $\frac{5}{2}^+$ [642] band (originating in the $\nu i_{13/2}$ shell-model state) in ^{169}Hf, which has been thoroughly studied in a cooperative effort of the Yale, Berkeley, and Brookhaven groups.[33]

B. Microscopic calculation of the phenomenological parameters

1. The Nilsson model

For the odd-neutron states, the g_K factor can be estimated using Eq. (5.29) of Löbner[29]

$$g_K=(g_s)_{\text{eff}}/2K\sum_{1}(a_{1K-(1/2)}{}^2-a_{1K+(1/2)}{}^2)\ , \quad (5)$$

TABLE V. Bands ($\Omega^{\pi}[Nn_z\Lambda]$) included in the Coriolis coupling calculations for negative parity states, Nilsson energies (ϵ_μ), particle energies after pairing [$E_\mu=([\epsilon_\mu-\lambda_F]^2+\Delta^2)^{1/2}-\Delta$], occupation probability v^2, $\langle j^2\rangle$, predicted levels and wave functions.

			Nilsson states[a]		
			$\frac{1}{2}^-$ [301]	$\frac{3}{2}^-$ [301]	$\frac{5}{2}^-$ [303]
			ϵ_μ (MeV)=45.90	45.03	45.62
			E_μ (MeV)=0.251	0.814	0.408
			v^2=0.75	0.88	0.80
			$\langle j^2\rangle$=2.61	5.04	8.96
I	Energy (keV) ^{79}Kr	Calculated	Amount of Coriolis mixing, $f_{IK}{}^2$		
$\frac{1}{2}^-$	0	$\equiv$0	1		
$\frac{3}{2}^-$	183	248	1.00	0.00	
$\frac{5}{2}^-$	147	292	0.05	0.02	0.93
	402	317	0.94	0.00	0.05
$\frac{7}{2}^-$	450	621	0.00	0.03	0.96
	695	892	0.97	0.02	0.00
$\frac{9}{2}^-$	814	1053	0.21	0.02	0.76
	1063	1009	0.78	0.04	0.19
$\frac{11}{2}^-$	1171	1558	0.00	0.08	0.92
	1450	1920	0.93	0.05	0.02
$\frac{13}{2}^-$	1662	2187	0.16	0.05	0.79
	1915	2093	0.82	0.06	0.12
$\frac{15}{2}^-$	2057	2874	0.01	0.13	0.87
$\frac{17}{2}^-$	2643	3705	0.17	0.08	0.76
$\frac{19}{2}^-$	3061	4387	0.02	0.14	0.84

[a]The shell model parameters $\kappa=0.05$ and $\mu=0.35$, the Fermi level $\lambda_F=46.82$ MeV, and $\hbar^2/2\mathscr{I}=0.05$ MeV were used.

where $a_{1\Lambda}$ is the amplitude of the wave function expanded in the basis $|N1\Lambda\Sigma\rangle$. Assuming that the $K=\frac{1}{2}^-$ and $K=\frac{5}{2}^-$ bands are based on pure $\frac{1}{2}^-$ [301] and $\frac{5}{2}^-$ [303] states, respectively, and adopting $(g_s)_{\rm eff}=0.7(g_s)_{\rm free}$ as suggested by Bohr and Mottelson (see p. 304 in Ref. 22) we obtain $g_{K=1/2}=2.44$ and $g_{K=5/2}=0.49$. This latter result agrees very well with both phenomenological values derived for the $K=\frac{5}{2}^-$ band. On the other hand, the theoretical $g_{K=1/2}$ is in excellent agreement with the positive experimental value $g_{K=1/2}=2.3\pm0.2$. The magnetic decoupling parameter is evaluated using Eq. (37b) from Ref. 25, the result, $b_0=0.11$, being within the limits of the experimental value $b_0=0.05\pm0.06$. In addition, Eq. (19) of Ref. 25 was used to calculate the decoupling parameter $a=0.72$, which is much larger than the phenomenological values listed in Table III.

Assuming that both levels involved in the 147.1 keV gamma-ray transition are pure $\frac{5}{2}^-$ [303] and $\frac{1}{2}^-$ [301] Nilsson states we obtain for this interband transition $B_N(E2)=6.2\times10^{-4}e^2b^2$. This value yields a hindrance factor $F_N=B_N(E2)/B_{\rm exp}(E2)=0.08$. Such a discrepancy becomes even larger if one takes into account the pairing interaction in the theoretical calculations. It is known that the $E2(|\Delta K|=2)$ transitions show F_N values ranging from 3×10^{-3} to 30 (see p. 163 of Ref. 29).

2. *Particle plus rotor model*

We provide here an interpretation of the experimental results in the framework of a Nilsson quasiparticle-plus-rotor (QPR) model. The total Hamiltonian, which couples the motion of the odd neutron to the core, is given by[22]

$$H = H_{qp} + (\hbar^2/2\mathscr{I})(\vec{I}^{\,2} + \vec{j}^{\,2} - 2\vec{I}\cdot\vec{j}) , \quad (6)$$

where H_{qp} is the Hamiltonian of the particle in the absence of rotation (a Nilsson Hamiltonian[25] including the pairing interaction) and $\vec{I}$ is the total angular momentum of the system composed of the core rotational angular momentum $\vec{R}$ plus the odd neutron angular momentum $\vec{j}$. The core is considered an axially symmetric rigid rotor. The term $\vec{I}\cdot\vec{j}$ gives rise to the so-called Coriolis effects.

This model has already been applied to $A = 70-80$ deformed nuclei. The odd proton isotopes in this region (Ga, As, Br) have been calculated by Scholz and Malik.[34] Calculations of the odd neutron nuclei (Ge, Se, Kr) have been performed by Sanderson,[35] Heller and Friedman,[36] Kreiner and Mariscotti,[37] Lipták and Krištiak,[16] and Behar *et al.*[38] In particular, the ^{79}Kr nucleus has been calculated in these latter references, where for the positive-parity states there are theoretical results available for levels up to $I = \frac{15}{2}^+$. However, to discuss carefully the possibility of a decoupled basis it is necessary to have at hand more information. Therefore, we have undertaken such calculations too.

The Hamiltonian (6) is diagonalized on the basis of strong-coupling wave functions ($\Omega^\pi[Nz_z 1]$). Both the negative- and positive-parity bands were studied. Summaries of properties of the Nilsson orbitals included in the calculations are given in Tables V and VI. The deformation is fixed $\delta_N = 0.3$. As was pointed out before, this value of δ_N can be derived from the $B(E2)$ value of ^{78}Kr. We adopt the usual pairing treatment which does not take into account the effects of blocking. The pairing gap parameter Δ is chosen to be 1.56 MeV as deduced from the odd-even Kr mass differences. The Fermi surface λ_F is taken from the Bardeen-Cooper-Schrieffer (BCS) calculation. The energies and Coriolis mixing coefficients $f_{1K}{}^2$ listed in Table V indicate that there is very little mixing of basis states in both the $K = \frac{1}{2}^-$ and the $K = \frac{5}{2}^-$ bands, as expected in view of the relatively small values of I and j involved. This fact gives support to the good overall agreement obtained with the leading-order description given in Secs. IV A 1 and IV B 1. The calculated energy sequence is compared with the experimental one in Table V. The agreement for the $K = \frac{5}{2}^-$ band is fairly good, but the absence of staggering in the ground-state band cannot be interpreted, since there is no allowed mixing with other

TABLE VI. Bands ($\Omega^\pi[Nn_z\Delta]$) included in the Coriolis coupling calculations for parity states, Nilsson energies (ϵ_μ), particles energies after pairing [$E_\mu = (\epsilon_\mu - \lambda_F{}^2 + \Delta^2)^{1/2} - \Delta$], occupation probability v^2, $\langle j^2 \rangle$, predicted levels and wave functions.

			Nilsson states[a]				
			$\frac{1}{2}^+$ [440]	$\frac{3}{2}^+$ [431]	$\frac{5}{2}^+$ [422]	$\frac{7}{2}^+$ [413]	$\frac{9}{2}^+$ [404]
			ϵ_μ (MeV)=40.60	41.72	43.54	45.58	48.65
			E_μ (MeV)=2.13	1.16	0.05	0.92	3.39
			v^2=0.95	0.91	0.63	0.11	0.03
			$\langle j^2 \rangle$=20.62	22.57	23.90	24.60	24.75
	Energy (keV)						
I	^{79}Kr	Calculated	Amount of Coriolis mixing, $f_{IK}{}^2$				
$\frac{7}{2}^+$	$\equiv 0$	$\equiv 0$	0.01	0.14	0.58	0.28	
$\frac{9}{2}^+$	19	51	0.08	0.20	0.48	0.23	0.01
$\frac{5}{2}^+$	161	118	0.04	0.18	0.78		
$\frac{11}{2}^+$	767	509	0.02	0.17	0.49	0.29	0.03
$\frac{13}{2}^+$	846	799	0.14	0.25	0.40	0.19	0.02
$\frac{15}{2}^+$	1533	1739	0.02	0.19	0.46	0.28	0.04
$\frac{17}{2}^+$	1872	2179	0.19	0.29	0.35	0.15	0.02
$\frac{19}{2}^+$		3630	0.02	0.21	0.45	0.27	0.04
$\frac{21}{2}^+$	3016	4181	0.24	0.31	0.31	0.13	0.02

[a]The shell model parameters $\kappa = 0.05$ and $\mu = 0.45$, the Fermi level $\lambda_F = 43.95$ MeV, and $\hbar^2/2\mathscr{I} = 0.08$ MeV were used.

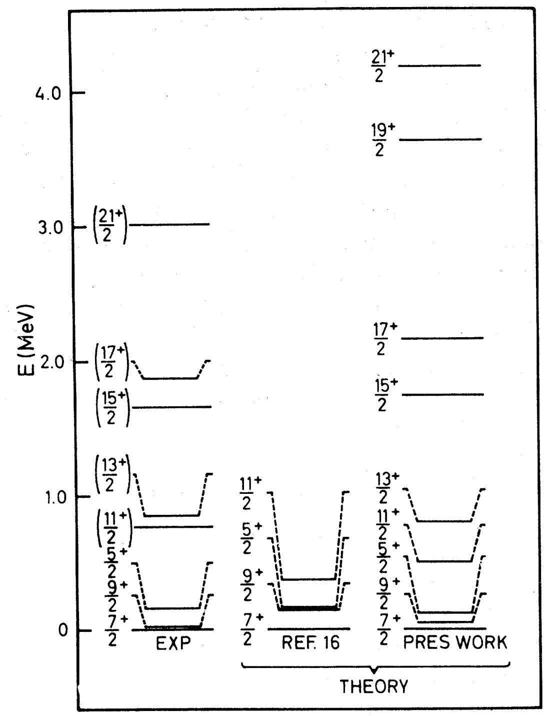

FIG. 5. The positive parity states from the ^{78}Se(α,3n) ^{79}Kr reaction compared with the present Coriolis coupling calculations and those of Ref. 16.

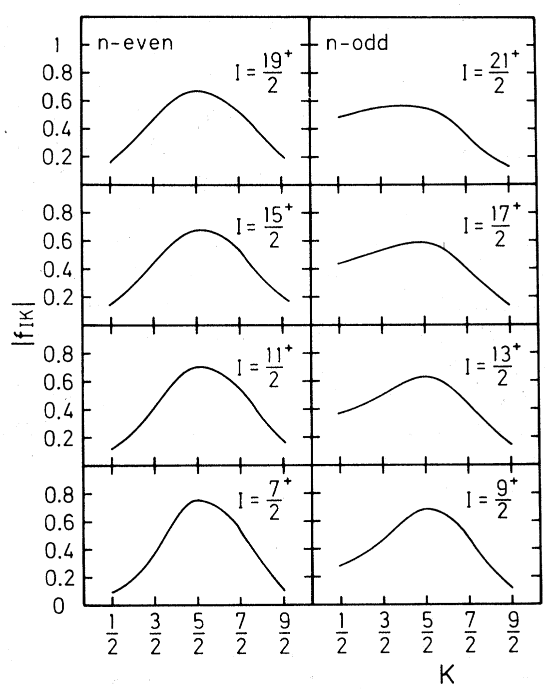

FIG. 6. Amplitude over the five Nilsson basis states for each total angular momentum I.

$K=\frac{1}{2}^-$ bands. This latter feature could be improved, in principle, by including the $\frac{1}{2}^-$ [310], $\frac{1}{2}^-$ [321], and $\frac{3}{2}^-$ [312] Nilsson orbitals in the calculation. However, the effects of such orbitals do not significantly change the results of Table V (cf., for instance, Ref. 36) and therefore the small phenomenological value of a remains unexplained. This discrepancy between the theoretical and the experimental values of the decoupling parameter could be partially ascribed to the influence of the gamma vibration. In fact, Bés and Ji-Ching[30] have demonstrated that the inclusion of vibration-particle coupling causes a significant change of the single-particle value of the decoupling factor in the right direction.

Although the Coriolis interaction for the negative-parity levels is small, the large value of Q_0 causes the Coriolis mixing to introduce sizable effects on the $E2(|\Delta K|=2)$ interband transitions. Using the coefficients f_{IK} listed in Table V we obtained $B(E2)=3.2\times10^{-3}e^2b^2$ for the interband 147.1 keV transition. This value is only about two times smaller than the experimental one. For the sake of completeness we also calculated the transition rate for the $\frac{7}{2}^-$ (267.0 keV) $\frac{3}{2}^-$ interband transition, obtaining $B(E2)=2.5\times10^{-3}e^2b^2$. This result combined with the leading order estimation for the $\frac{7}{2}^-$ (302.5 keV) $\frac{5}{2}^-$ intraband transition gives an intensity ratio of about 0.01, which is smaller than the experimental value 1.3/19=0.07. The mixing with the gamma vibrational state may also account for these remaining discrepancies.

For the positive-parity calculations we included all the Nilsson states arising from the unique-parity $g_{9/2}$ orbital. In Table VI we provide results of diagonalizing Eq. (6) for the lowest state of each spin up to $I=\frac{21}{2}^+$. The calculated energies are compared with the experimental level scheme in Fig. 5. The agreement is quite good. In fact, the lowering of the $\frac{7}{2}^+$ state is predicted and the level spacing of

TABLE VII. Comparison of experimental and theoretical spectroscopic factors.

E (keV)	l_n	I	S_j (exp)	S_j (theor.) Ref. 16	PW
0.0	1	$\frac{1}{2}^-$	0.305	0.57	0.34
148.8	4	$\frac{9}{2}^+$	0.512	0.21	0.27
182.8	1	$\frac{3}{2}^-$			0.04
384.0[a]	1	$\frac{3}{2}^-$	0.366	0.08	0.20

[a]This level belongs to the $\frac{3}{2}^-$ [301] band which is not populated in the present experiment.

the $\frac{7}{2}^+$, $\frac{9}{2}^+$, and $\frac{5}{2}^+$ states is reproduced. The observed $\frac{21}{2}^+$ state is lower than the calculated energy. This discrepancy might be explained by introducing the variable moment of inertia (VMI) effects and the three-quasiparticle states which were not included in the calculation.

A glance at Table VI indicates that this band is mainly based on the $\frac{5}{2}^+$ [422] state. However, a considerable amount of admixture was obtained. It is convenient to classify sets of states in terms of their angular momenta relative to the bandhead angular momentum $I_0=\frac{7}{2}$

$$I=I_0+n \tag{7}$$

since Coriolis mixing in this case plays a different role in states with n even and states with n odd. In Fig. 6 we plotted $|f_{IK}|$ over the five Nilsson basis states for each total angular momentum I. It is evident that the positive-parity yrast states do not have dominant $K=\frac{1}{2}$ components. Consequently, this band is not decoupled in the full meaning of the Stephens definition.[39] Therefore, contrary to the suggestion of Clements et al.,[17] this band cannot be interpreted as arising from the decoupling of the $g_{9/2}$ neutron from the ^{78}Kr core. However, there is considerable mixing, so that the band is not quite strong coupled either. The contribution to the n-odd states from low-$K(\Omega)$ Nilsson orbitals increases with increasing spin.

The reduced transition probability for the transitions $\frac{21}{2}^+ \to \frac{17}{2}^+$ can be evaluated with the formula

$$B(E2;I_i=\tfrac{21}{2}^+ \to I_f=\tfrac{17}{2}^+)=(5e^2Q_0^2/16\pi)\sum_K f_{21/2K}f_{17/2K}\langle \tfrac{21}{2}2K0\,|\,\tfrac{17}{2}K\rangle^2 . \tag{8}$$

Using the coefficients f_{IK} calculated in the present work we obtained $B(E2)=0.23\ e^2b^2$, which yields $T_{1/2}=0.13$ psec for this 1143.8 keV transition. This value is smaller than the experimental lower limit $T_{1/2}\geq 1.0$ psec.

For the sake of completeness we also calculated some spectroscopic factors for the (d,p) stripping reaction using the formula

$$S_I(d,p)=2/(2I+1)\left[\sum_K f_{IK}C_{IK}U_{IK}\right]^2 , \tag{9}$$

where U_{IK} is the quasiparticle level emptiness, and C_{IK} is the expansion coefficient of the deformed state of the odd particle in the spherical basis. The results are listed in Table VII, where the comparison with the experimental data of Chao et al.[15] and the calculation of Lipták and Krištiak[16] is made. A satisfactory overall agreement between the experimental data and theoretical results is obtained. In particular, our predictions are better than those of Ref. 16 for the ground-state ($\frac{1}{2}^-$) and 384.0 keV ($\frac{3}{2}^-$) levels. The 182.8 keV ($\frac{3}{2}^-$) level has not been observed in the (d,p) reaction. This is in agreement with the small calculated value $S_{3/2}$ (182.8 keV)$=$0.04.

In conclusion we would like to emphasize that the Coriolis-coupling model seems to be able to account for the general properties of states in the ^{79}Kr nucleus. The remaining differences could indicate that other degrees of freedom, e.g., gamma vibration,[30] become operative, and further theoretical work in this direction is needed.

ACKNOWLEDGMENTS

The authors are indebted to Dr. A. J. Kreiner for his suggestions in the early stages of this work. They are also grateful to Prof. D. R. Bés for stimulating discussions and enlightening advice. One of us (L.S.) thanks the staff at the Departamento de Física of the Comisión Nacional de Energía Atómica for the kind hospitality afforded to him during the performance of this work. This work has been carried out under the auspices of Consejo Nacional de Investigaciones Cientificas y Técnicas, (CONICET), Argentina and the National Science Foundation and Department of Energy of the USA, Contract INT 79-00351. L.S. is a fellow of the Consejo Nacional de Investigaciones Cientificas y Técnicas, Argentina.

[1]P. von Brentano, B. Heits, and C. Protop, *Problems of Vibrational Nuclei,* edited by G. Alaga, V. Paar, and L. Sips (North-Holland, Amsterdam, 1974), p. 155.

[2]*Proceedings of the International Conference on the Structure of Medium-Heavy Nuclei, Rhodos, Greece, 1979,* Conference Series No. 49 (Institute of Physics, Bristol, 1980).

[3]M. Behar, A. Filevich, G. García Bermúdez, A. M. Hernández, and M. A. J. Mariscotti, Nucl. Phys. A261, 317 (1976).

[4]K. O. Zell, B. Heits, W. Gast, D. Hippe, W. Schuh, and P. von Brentano, Z. Phys. A 279, 373 (1976).

[5]K. O. Zell, H.-G. Friederichs, B. Heits, P. von Brentano, and C. Protop, Z. Phys. A 272, 27 (1975).

[6]N. E. Sanderson and R. G. Summers-Gill, Nucl. Phys. A261, 93 (1976).

[7]K. O. Zell, H.-G. Friederichs, B. Heits, D. Hippe, H. W. Schuh, P. von Brentano, and C. Protop, Z. Phys. A 276, 371 (1976).

[8]K. O. Zell, B. Heits, D. Hippe, W. Schuh, and P. von Brentano, Z. Phys. A 292, 135 (1979).

[9]E. Nolte and P. Vogt, Z. Phys. A 275, 33 (1975).

[10]S. L. Andersen, K. Hangeto, A. Isnes, I. Bergström, and Z. P. Sawa, Annual Report, Research Institute of Physics, Stockholm, 1971, p. 107.

[11]K. Forssten, F. Ingebretsen, W. Waluś, and Z. P. Sawa, Annual Report, Research Institute of Physics, Stockholm, 1974, p. 96.

[12]F. Ingebretsen, W. Waluś, and Z. P. Sawa, Annual Report, Research Institute of Physics, Stockholm, 1974, p. 99.

[13]Z. P. Sawa, K. Forssten, F. Ingebretsen, and W. Waluś, Fizica 7, Suppl. 2, 138 (1975).

[14]S. M. Bharathi, Y. K. Agarwal, B. Lal, C. V. K. Baba, M. G. Betigeri, and N. G. Puttaswamy, Pramana 4, 25 (1975).

[15]J. Chao, D. K. Olsen, C. Newsom, and P. J. Riley, Phys. Rev. C 11, 1237 (1975).

[16]J. Lipták and J. Kristiak, Nucl. Phys. A311, 421 (1978).

[17]J. S. Clements, L. R. Medsker, L. H. Fry, Jr., and L. V. Theissen, Phys. Rev. C 21, 1285 (1980).

[18]E. der Mateosian and A. W. Sunyar, Nucl. Data Tables 13, 391 (1974).

[19]A. E. Blaugrund, Nucl. Phys. 88, 501 (1960).

[20]J. Lindhard, M. Scharff, and H. E. Schiott, K. Dan. Vidensk. Selsk. Mat. Fys. Medd. 33, No. 14 (1963).

[21]P. P. Urone and D. C. Kocher, Nucl. Data Sheets 15, 257 (1975).

[22]A. Bohr and B. R. Mottelson, *Nuclear Structure* (Benjamin, New York, 1975), Vol. II.

[23]L. R. Greenwood, Nucl. Data Sheets 15, 289 (1975).

[24]F. Boehm, G. Goldring, G. B. Hagemann, G. D. Symons, and A. Tveter, Phys. Lett. 22, 627 (1966); 23, 491 (E) (1966).

[25]S. G. Nilsson, K. Dan. Vidensk, Selsk. Mat. Fys. Medd. 29, No. 16 (1955).

[26]H. P. Hellmeister, U. Kaup, J. Keinonen, K. P. Lieb, R. Rascher, R. Ballini, J. Delaunay, and H. Dumont, Phys. Lett. 85B, 34 (1979).

[27]H.-G. Friederichs, A. Gelberg, B. Heits, K. P. Lieb, M. Uhrmacher, K. O. Zell, and P. von Brentano, Phys. Rev. Lett. 34, 745 (1975).

[28]J. Bleck, D. W. Haag, W. Leitz, and W. Ribbe, Phys. Lett. 26B, 134 (1968).

[29]K. E. G. Löbner, *The Electromagnetic Interaction in Nuclear Spectroscopy,* edited by W. D. Hamilton (North-Holland, Amsterdam, 1975).

[30]D. R. Bés and C. Yi-Chung, Nucl. Phys. 86, 581 (1966).

[31]R. Broda, M. Rybicka, J. Styczeń, W. Waluś, and K. Królas, Acta Phys. Pol. B3, 263 (1972).

[32]M. Budzynsky, V. S. Buttsev, K. Ya Gromov, R. Ion Mikhay, V. G. Kalinnikov, N. Z. Marupov, V. A. Morozov, T. M. Muminov, I. Kholbaev, and M. Yakhim, Yad. Fiz. 21, 913 (1975) [Sov. J. Nucl. Phys. 21, 469 (1975)].

[33]I. Rezanka, I. M. Ladenbauer-Bellis, J. O. Rasmussen, W. Ribbe, and E. der Mateosian, Phys. Rev. C 11, 1767 (1975).

[34]W. Scholz and F. B. Malik, Phys. Rev. 176, 1355 (1968).

[35]N. E. Sanderson, Nucl. Phys. A216, 173 (1973).

[36]S. L. Heller and J. N. Friedman, Phys. Rev. C 10, 1509 (1974); C 12, 1006 (1975).

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

[38]M. Behar, D. Abriola, A. Filevich, G. Garcia Bermúdez, A. J. Kreiner, and M. A. J. Mariscotti, J. A. Pinston, and D. Barneaud, Nucl. Phys. A376, 131 (1982).

[39]F. S. Stephens, Rev. Mod. Phys. 47, 43 (1975).