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J.Lipták, K.Krištiaková, J.Krištiak

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Липтак Я. и др. **E6 - 10254**

Свойства уровней ^{81}Kr, заселяемых при распаде изомеров ^{81}Rb

Изучен электронный захват и β^+-распад ^{81m}Rb и ^{81g}Rb. С помощью Ge(Li) и Si(Li) детекторов исследованы спектры гамма-лучей, электронов внутренней конверсии и гамма-гамма совпадений.

Для 14 переходов определены коэффициенты внутренней конверсии и мультипольности. На основе значений log ft и мультипольностей переходов определены спины и четности возбужденных состояний. Обсуждается структура возбужденных состояний ^{81}Kr.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Lipták J. et al. **E6 - 10254**

Properties of ^{81}Kr Levels Populated in the Decay of ^{81}Rb Isomers

The β^+-decay of ^{81}Rb ground and isomeric states (4.58h and 30.25 min) has been studied with Ge(Li) detectors in both single and coincidence modes. The decay of ^{81}Rb isomer ($T_{1/2}$ = 30.25±0.25 min) has been investigated for the first time. The relative electron intensities of fourteen transitions in ^{81}Kr have been measured with a magnetic- Si(Li) spectrometer and an iron-free toroidal magnetic spectrometer. The internal conversion coefficients have been determined by the normalized electron-to-γ ray ratio method. The multipolarities of the transitions were deduced. The spin-parity assignments have been made from the consideration of the logft values, the transition multipolarities and the γ-ray branching ratios. A probable structure of some of the excited states in the ^{81}Kr nucleus is discussed.

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1. *INTRODUCTION*

While the β^+- EC decay of ^{81}Rb (4.58 h) has been the subject of several investigations /1-4/ information concerning the β^+-EC decay of the ^{81}Rb isomer (31.5 *min*)/4/as well as the properties of the leves in ^{81}Kr has remained sparse. One would expect that the properties of low-lying levels in the neutron deficient $^{81}_{36}$Kr$_{45}$ nucleus should be complex since this nucleus has 5 neutron holes in the N = 50 shell.

Recently, the structure of the levels of odd A nuclei in the vicinity of N or Z = 50 has been examined theoretically using different approaches ranging from the shell model with a residual interaction to the Coriolis-coupling model of the odd particle in the deformed nucleus, refs./5-8/. Further, the interesting problem exists for the nuclei of the mass number A~81 in which the unique-parity level of large spin j in the major shell ($1g_{9/2}$) is being filled by neutrons. There is a competition between a spin j and a spin (j-1) state for the ground state. The simple shell model cannot account for the low-lying (j-1) state and therefore such an extra low-lying state with spin J = j - 1 and with the unique parity has been called the anomalous coupling state. The structure of such states is not clear but two theories (Paar/6/ and Kuriyama et al./7/) have attempted to explain it thoroughly. Furthermore, Bohr and Mottelson/9/ have pointed out a possible connection between the appearance of the (j-1) state as the ground state and the quadrupole deformation of the nucleus. In this connection it is thought worthwhile to continue the systematic investigations of the level structure of Sr and Kr odd nuclei with the mass number A=77–85.

2. EXPERIMENTAL APPARATUS AND PROCEDURES

The short and long-lived ^{81}Rb activity were prepared by the bombardment of a Zr target (0.1 *mm* thick), using 660 *MeV* protons in the external beam of the synchrocyclotron, JINR, Dubna. The sources were made of a mixture of spallation products by the electromagnetic mass-separation technique, using a surface ionization source together with the hot solid target method/10/.

The internal conversion measurements were made with ^{81g}Rb sources prepared by the implantation of ^{81}Rb ions into the Al backing.

For the γ-ray single measurements a 41 cm^3 coaxial Ge(Li) detector was used. The system resolution was 2.5 *keV* (FWHM) for the 1332 *keV* γ-ray of ^{60}Co. Two source-detector geometries were used: (a) close geometry, a source on the top of the detector housing; (b) distant geometry, the source at a distance 5.5 *cm* from the detector housing. The cascade-sum contribution for the stronger γ-rays was estimated from the γ-ray spectra taken at a distant geometry.

Coincidence experiments were performed with 41 and 50 cm^3 coaxial Ge(Li) detectors (FWHM=2.5 *keV* for the 1332 *keV*). The time resolution of the coincidence system (2τ) was 100 *nsec*. Data were collected in the 4096 x 4096 channel matrix and stored on the magnetic tape. After measurements, the tape was analysed using a program/11/ written for the Hewlet-Packard 2116-C computer. The program stored the data into spectra, each of which was coincident with a particular window. Coincidence windows were set on the full-energy peaks of interest and on the background just above or below these peaks to account for events that are coincident with the Compton background.

The relative intensities of the β^+-decay of ^{81mg}Rb were determined by the measurements of I_γ (511 *keV*) in the distant geometry. An Al absorber (3 *mm* thick) was on both sides of the ^{81}Rb source.

Two types of spectrometers have been used to measure the electron spectrum of ^{81g}Rb. The intensities of the low-energy conversion lines (K 49.5 and 64.5 *keV*) were measured by the iron-free beta spectrometer with the toroidal magnetic field /12/. The resolution of the beta spectrometer was about 1%. The internal conversion of the higher-energy transitions was studied by the spectrometer which is a combination of the constant magnetic field (~750 *Gauss*) with the high-resolution Si(Li) detector /13/.

3. *RESULTS*

Typical γ-ray single spectra obtained for the ^{81m,g}Rb decay are shown in *Figs. 1,2*. The γ-rays were assigned to the respective parents by following their decay over a period of 15 h. A total of 48 and 44 γ-rays were identified as due to the decay of ^{81g}Rb and ^{81m}Rb, respectively. The energies of the most intense peaks in the ^{81g}Rb spectrum were taken from the works of Broda et al. /1/ and Waters et al. /2/. Some peaks from the decay of admixture of ^{82}Rb nuclei were used, too. These energies were taken as internal standards to determine the energies of weaker peaks. The peak positions of γ-rays were obtained with a computer program /11/ which fitted a Gaussian curve to the data points of the photopeak. The background was supposed to be straight. The energy calibration was determined by the least squares fit of the n-th degree polynomial to positions of the γ-rays taken as reference energy points. The 4 degree polynomial was found to give the best fit. The relative intensities of γ-rays were obtained from the peak areas determined from the area of a computer-fitted Gaussian curve. The relative efficiency curve /11/ was obtained using ^{54}Mn , ^{56}Co , ^{60}Co , ^{75}Se, ^{152}Eu , ^{169}Yb and ^{182}Ta standard sources. The γ-ray energies and intensities together with their relative decay mode, are summarized in *Table 1,* in which the results of Broda et al. /1/ and

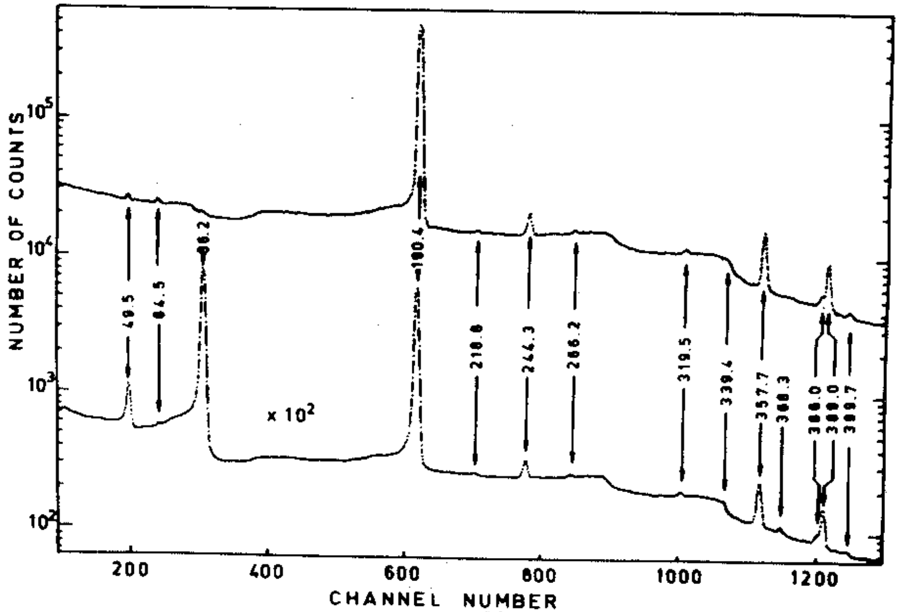


Fig. 1. Low-energy part of the ^{81m,g}Rb *γ -ray spectrum. The upper spectrum belongs to* ^{81g}Rb *and the lower one to* $^{81m+g}$ Rb.

those Waters et al. [2] are included for comparison. *Figs. 3,4* and *5* show several of the coincidence γ -ray spectra. A summary of the results of the γ–γ -coincidence experiments is given in *Table 2*. The observation of a γ-ray line in the spectrum coincident with a gating γ -ray is indicated in *Table 2* by the symbol Y or the value of its coincidence intensity calculated from the gated γ -ray spectra. Besides this the value of γ -ray intensity calculated from the proposed decay scheme is given to show the completness of the scheme.

It is impractical to discuss in detail the extensive data of *Table 2*. Instead, we would like to point at several cases where some explanation is needed. In the gate of 456.9 *keV* the observed intensity of the 244.3 *keV* transition is smaller than the calculated one. The same holds for the 446.3 *keV* transition in the gate of 602.3 *keV*. Similar discrepancies appear in the gate of 643.6 *keV* for 368.3 and 463.3 *keV* transitions. At present, no explanation of these discrepancies is available. Generally, good agreement was obtained between experimental coincidence intensities and intensities calculated from both proposed decay schemes. This agreement supports our point of view that all observed γ-transitions are placed correctly, apart those mentioned above.

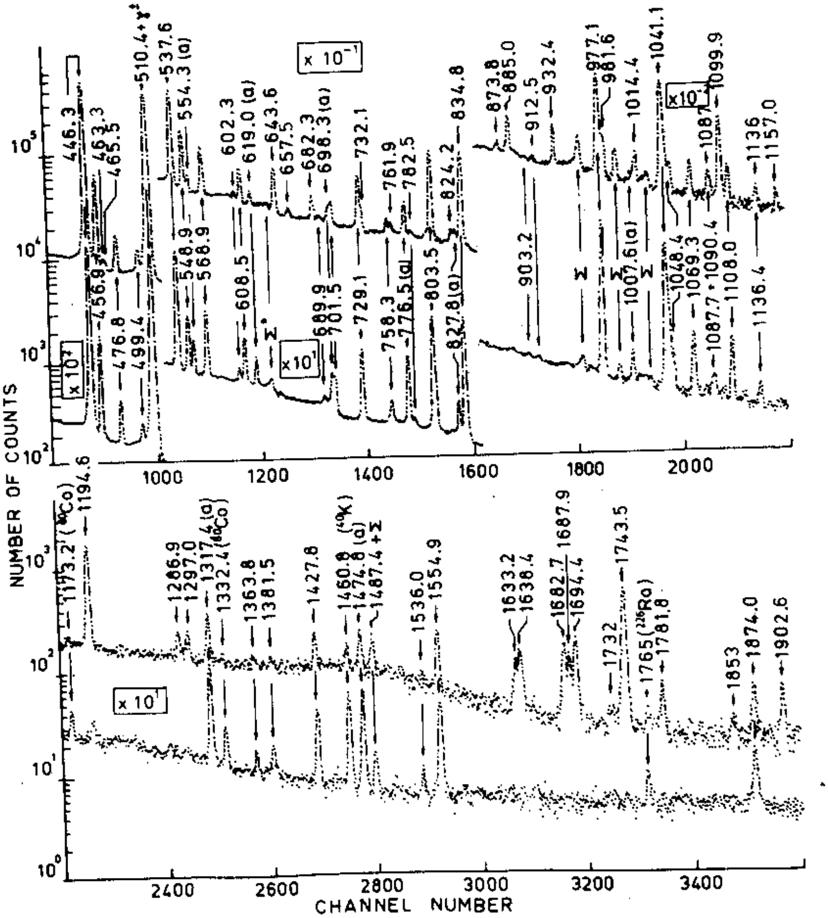


Fig. 2. *High-energy part of the* ^{81m,g}Rb γ *-ray spectrum. The upper spectrum belongs to* $^{81m+g}$Rb *and the lower one to* ^{81g}Rb. *Meaning of used symbols:* a - γ *-line belong to the decay of* ^{82}Rb . Σ - *a real sum peak of cascade transitions.* Σ^* - *a random sum peak.*

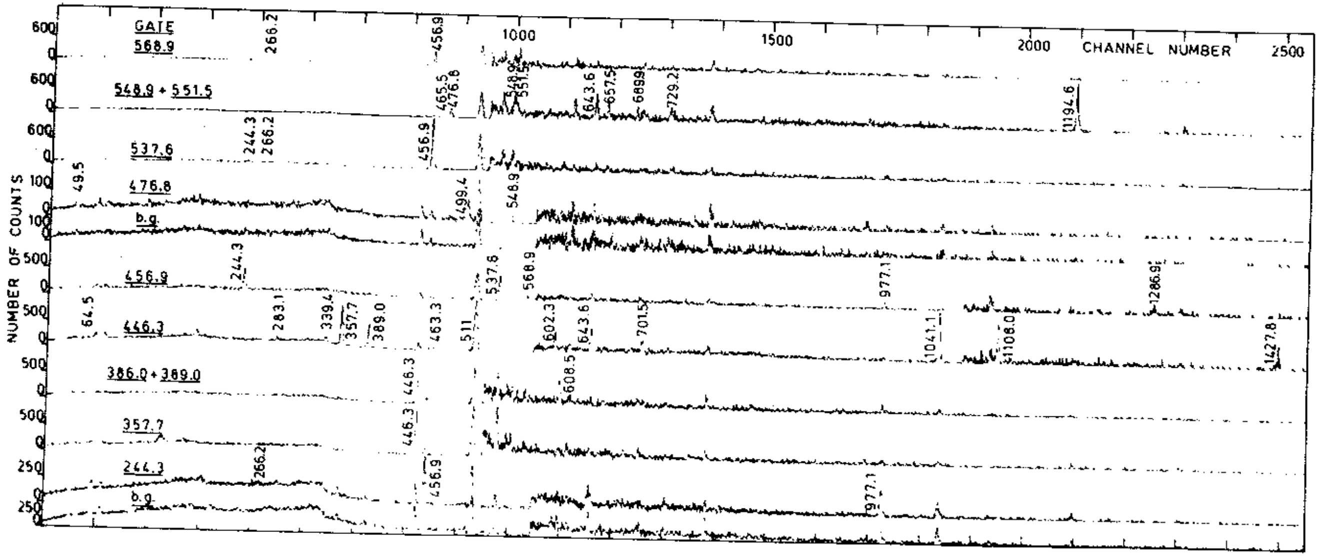


Fig. 3. The γ -ray spectra from the γ-γ coincidence measurements. The energy of the selected window is shown at the beginning of the spectrum. The abbrevation b.g. means a background window.

The comparison of measured γ-ray intensities from the decay of ^{81g}Rb with the values published by Broda et al.[1] and Waters et al.[2] shows good agreement among these values. One exception in this general agreement is the intensity of 190.4 *keV* transition. The intensity value of Waters et al.[2] agrees with our value (see *Table 1*) but both values disagree with Broda's value which is considerably larger. We have made special measurement of the intensity of 190.4 *keV* with the ^{81g}Rb source packed in a polyethylene bag because of 190.4 *keV* transition deexcites the isomer of volatile ^{81}Kr with $T_{1/2}$= 13 *sec* and therefore the origin of the discrepancy with Broda's value is not clear to us.

The relatively strong γ-transition of 510.4 *keV* energy, covered completely in a single spectra by the strong annihilation line, was observed in coincidence measurements. The existence of this transition is exposed in the 977.1 *keV* gate very clearly (see *Fig. 4*), as the 1677.9 *keV* level depopulated by 977.1 *keV* transition is not fed by β^+-transition (because of the decay energy).

The electron spectra obtained by both beta-spectrometers are shown in *Figs. 6* and *7*. The internal conversion electron intensities were determined relative to the value of 2.4 for the K electron peak of the 446.3 *keV* transition. These intensities are given in *Table 3* along with the relative photon intensities, the deduced K-shell internal conversion coefficients α_K (ICCα_K), the theoretical values of ICC's and the multipolarities of the transitions. The assumption of M1 multipolarity for the 446.3 *keV* transition is based on the fact that E1 or E2 assignment for the multipolarity of 446.3 *keV* transition leads to unreasonable α_K values for the other transitions. Moreover, this assumption is confirmed by the data from the Lemming's compilation[17]. The theoretical values of the internal conversion coefficients given in *Table 3* were obtained through graphical interpolation of the data from the Tables of Hager and Seltzer[18]. The M1 character of the 49.5 *keV* transition as determined from α_K value has been confirmed by the second independent method. The intensity balance analysis on the 49.5 *keV* level provided the value of total ICC α_{T}=

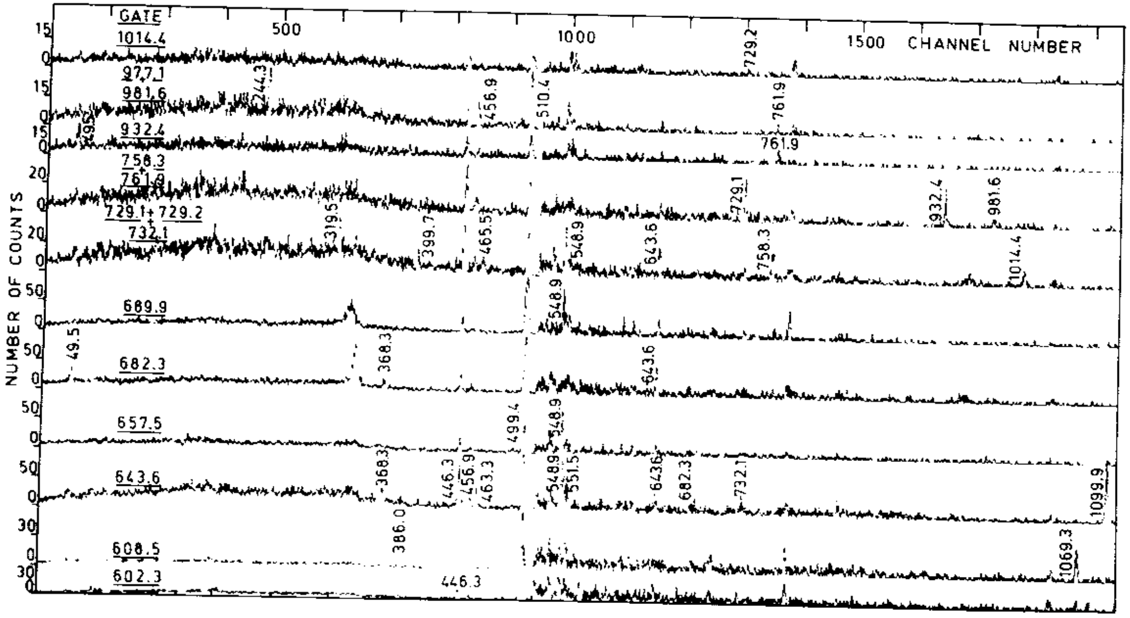


Fig. 4. Typical γ-γ coincidence data in the ^{81}Rb decay.

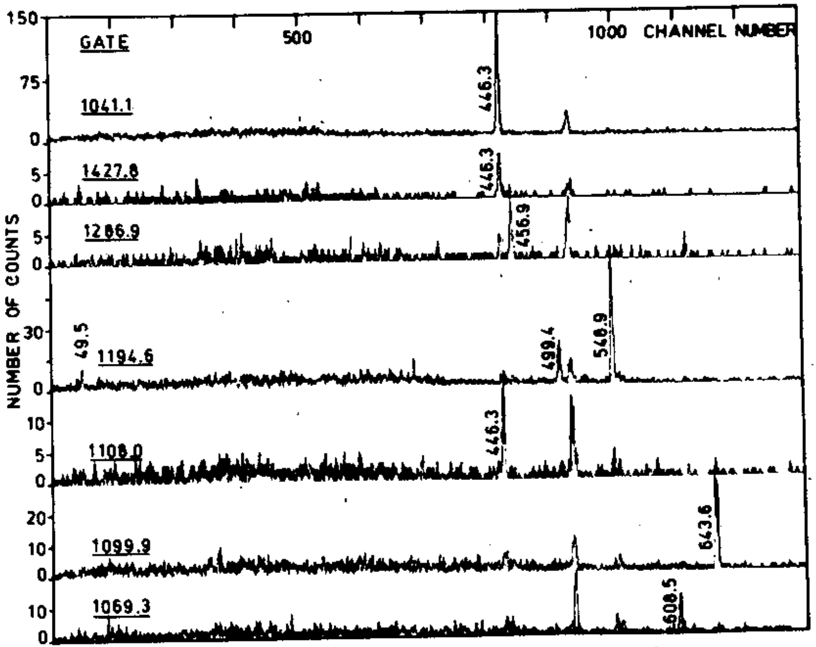


Fig. 5. The same, as in Fig. 4.

$=0.76\pm0.30$ as compared with the theoretical values $\alpha_T = 0.93$ for M1 type transition and $\alpha_T = 12.6$ for E2 type transition /18/. It follows, that the 49.5 *keV* transition is the magnetic dipole transition. The maximum value of E2 admixture in this transition is 6%.

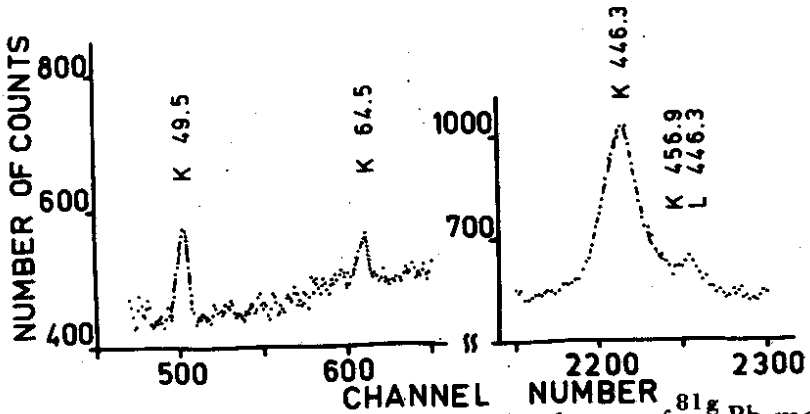


Fig. 6. Electron spectrum from the decay of ^{81g}Rb *measured with the iron-free beta-spectrometer.*

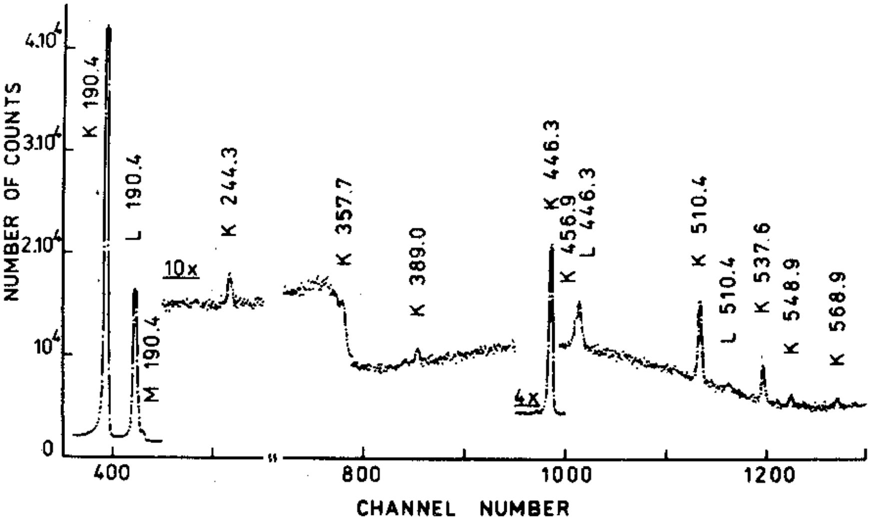


Fig. 7. Electron spectrum from the decay of ^{81g}Rb *measured with a* Si(Li) *detector.*

4. DECAY SCHEME

Both the decay schemes of ^{81m,g}Rb have been constructed on the basis of $\gamma-\gamma$ coincidence results, taking into account the intensities and energies of the relevant γ-transitions. The results obtained in the (d,p)/14/ and the (α,xn)/19/ nuclear reactions have been used, too. The logft values for β^+-EC feeding of levels in ^{81}Kr have been determined using the half-lives, the theoretical calculation of the EC/β^+ ratio/15/, the intensities of the γ-transitions and Q_{EC} values. The Q_{EC}= 2260±30 *keV* has been taken from the Wapstra's and Gove's compilation /16/.

4.1. *Decay of* ^{81g}Rb ($T_{1/2}$=*4.58 h)*

The proposed decay scheme of the ^{81}Rb ground state is shown in *Fig. 8.* Here, all 15 excited levels are

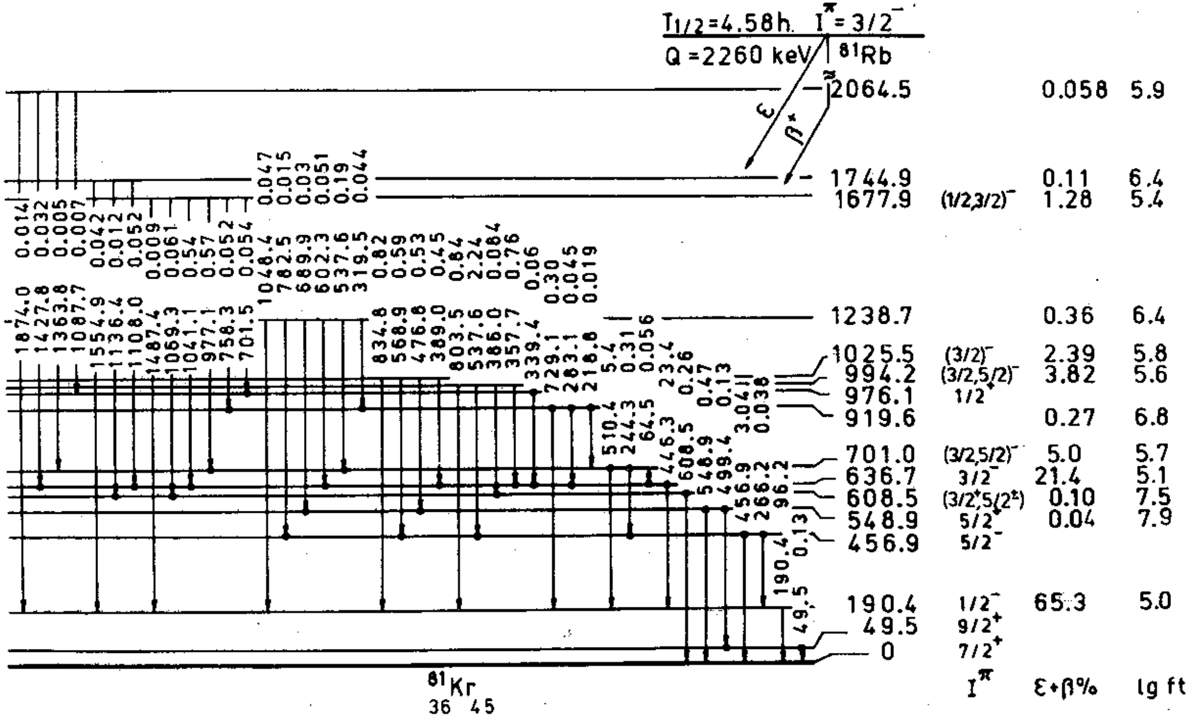


Fig. 8. Level scheme of ^{81}Kr populated in the decay of ^{81g}Rb. A dot indicates the coincidence relations. The intensities of the transitions are normalized on 100 decays of ^{81g} Rb.

introduced on the basis of $\gamma-\gamma$ coincidence results and 5 from these levels are suggested for the first time. Comparison of our results with the decay scheme proposed by Broda et al./1/ shows that the levels at 1108.1, 1280.2 and 1883 *keV* cannot be introduced. The relevant transitions of 499.4, 602.3, 1108.0 and 1427.8 *keV*, must be placed differently than they are in ref./1/, as the $\gamma-\gamma$ coincidence measurements show. All of the rest of Broda's proposed levels are confirmed by our results, but this is not the case as far as the positions of γ-transitions are concerned.

The analysis of the intensity balance on the 190.4 *keV* level, provided that α_T (E3, 190.4 *keV*) $= 0.49$/18/, together with the theoretical dependence of the EC/β^+ ratio on energy/15/ gives the decay energy $Q_{EC} = (2290^{+55}_{-43})$ *keV*. This value agrees with the tabulated value/16/ but it differs from $Q_{EC} = (2190 \pm 30)$ *keV* determined by Broda et al./1/.

The spin and parity of the ground state of ^{81}Kr is $7/2^+$/17/. The Ml character of the 49.5 *keV* transition (see *Table 3*) as well as the β^+-decay of ^{81m}Rb($J^\pi = 9/2^+$)/17/ to the 49.5 *keV* level gives $J^\pi = 9/2^+$ for this level. The same value has been obtained by Chao et al./14/ in the ^{80}Kr(d,p)^{81}Kr reaction study (the values of level energies given by Chao et al./14/ must be shifted about 49 *keV* up).

The 190.4 *keV* level has $J^\pi = 1/2^-$ as follows from E3 character of 190.4 *keV* transition to the ground state ($J^\pi = 7/2^+$) and the allowed β^+-transition to this level from the ground state of ^{81}Rb($J^\pi = 3/2^-$)/17/. Again, the corrected results of Chao et al./14/ confirm this assignment.

The value of J^π for 456.9 *keV* level is $5/2^-$ as follows from the E1 multipolarity of 456.9 *keV* transition to the ground state ($J^\pi = 7/2^+$) and the E2 character/17/ of 266 *keV* transition to 190.4 *keV* level ($J^\pi = 1/2^-$).

Chao et al./14/ have reported $J^\pi = 5/2^+$ for the 551 *keV* level probably identical with the state at 548.9 *keV*. Such assignment does not contradict to Ml , E2 character of 548.9 *keV* transition which de-excites this level to g.s. ($J^\pi = 7/2^+$).

The most probable value of J^{π} for 608.5 *keV* level is $3/2^{+}$ or $5/2^{\pm}$ because relatively strong transition of 608.5 *keV* populates the ground state with the high value of $J^{\pi} = 7/2^{+}$.

The level at the energy of 636.7 *keV* has $J^{\pi} = 3/2^{-}$. These quantum characteristics follow from the M1 character of 446.3 *keV* transition, allowed β^{+}-transition ($\log ft = 5.1$) from the g.s. of ^{81}Rb $J^{\pi} = 3/2^{-}$)and γ-ray branching of 1099.9 *keV* level ($J^{\pi} = 5/2^{+}$).

Since the 64.5 *keV* transition is magnetic dipole transition as well as the 244.3 *keV* transition we propose $3/2^{-}$ or $5/2^{-}$ as the possible spin and parity of 701.0 *keV* level.

As is seen in *Fig. 8*, the EC-transitions to the 994.2 and 1677.9 *keV* levels have $\log ft = 5.6$ and 5.4, respectively. The allowed character of these indicates the negative parity and admits three spins, 1/2, 3/2 and 5/2 for 994.2 and 1677.9 *keV* levels. As branching ratios of the 357.7 *keV* and 537.6 *keV* transitions as well as the 803.5 *keV* transition show we propose $3/2^{-}$ or $5/2^{-}$ as quantum characteristics of the 994.2 *keV* excited level. The intensity analysis of the γ-rays from the 1677.9 *keV* level leads to the suggestion that the quantum characteristics of this level are $3/2^{-}$ or $1/2^{-}$.

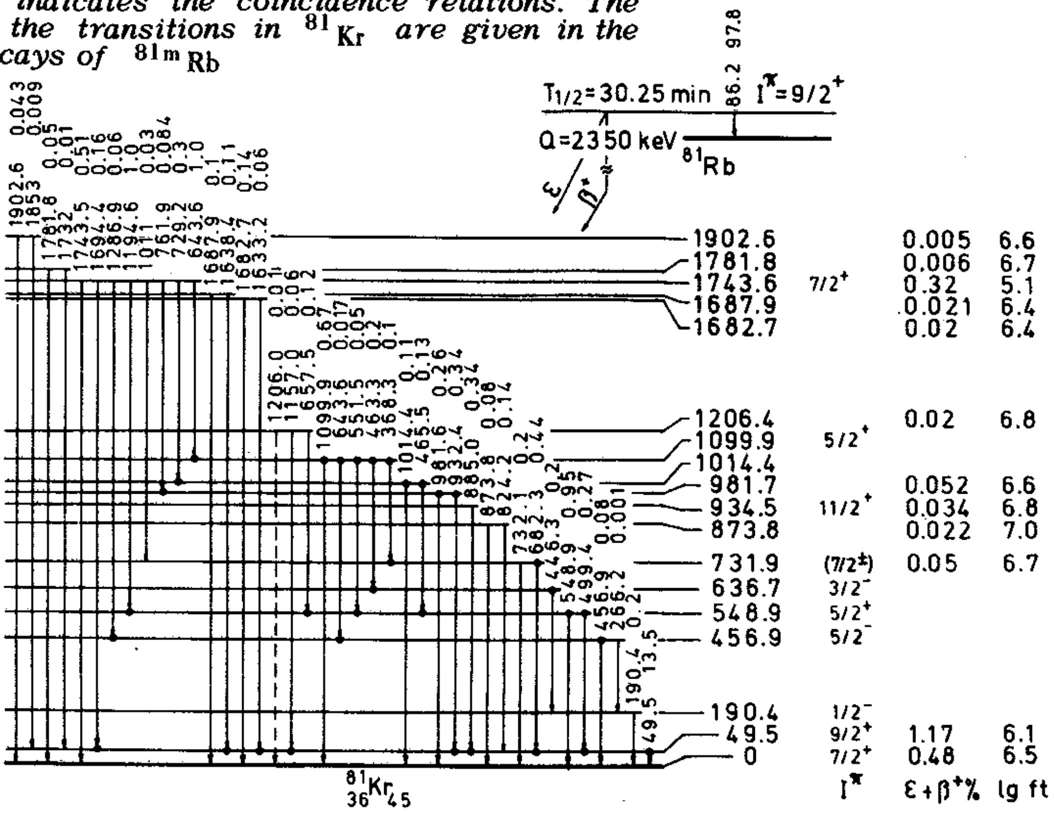
The branching ratio of the 389.0 *keV* (M1)and 834.8 *keV* transitions shows that the most probable multipolarity of 834.8 *keV* transition is M1. Therefore, we propose $J^{\pi} = 3/2^{-}$ for the 1025.5 *keV* level.

4.2. *Decay of* ^{81m}Rb *(30.25±0.25) min*

The new value of the half-life of the ^{81}Rb isomer, $T_{1/2} = 30.25$ 0.25 *min*, has been determined by measuring the time behaviour of the intensity of the 86.2 *keV* isomeric transition.

The spin of the isomeric state has been measured by the atomic beam method and its value is 9/2 /17/. The E3 character /17/ of 86.2 *keV* isomeric transition to ^{81g}Rb($3/2^{-}$)leads to the positive parity of ^{81m}Rb.The total ICC of the 86.2 *keV* transition $\alpha_{T} = 19.5$, was determined from Hager's and Seltzer's ICC Tables /18/ by interpolation. This value of α_{T} was used to calculate the

Fig. 9. Level scheme of ^{81}Kr *populated in the decay of* ^{81m}Rb. *A dot indicates the coincidence relations. The intensities of the transitions in* ^{81}Kr *are given in the unit of 1000 decays of* ^{81m}Rb



isomeric branching ratio which is 2.2%. The values of log ft were calculated by using this branching ratio and $Q_{EC} = 2350$ *keV*. As *Figures 8* and *9* show, 5 levels excited in the decay of ^{81}Rb ground state also have been seen in the decay of the isomeric state of ^{81}Rb, namely 49.5 ($9/2^+$), 190.4 ($1/2^-$), 456.9 ($5/2^-$), 548.9 ($5/2^+$) and 636.7 *keV* ($3/2^-$) states.

The similar arguments as for the ^{81g}Rb decay (empirical rules for log ft values [20], γ - ray branching ratios) have been applied to the ^{81m}Rb decay study, too. It follows that the most probable spins and parities of the 731.9, 1099.9 and 1743.6 *keV* level are $7/2^{\pm}$, $5/2^+$ and $7/2^+$, respectively.

The state at the energy of 934.5 *keV* has $J^{\pi} = 11/2^+$ as follows from the study of the (α,xn) reaction [19]. The results of the (d,p) reaction [14] indicate $J^{\pi} = 5/2^+$ for the 1099.9 *keV* level in conformity with our suggestion.

Three levels, 873.8, 1781.8 and 1902.6 *keV*, have been introduced on the basis of energy sums only. But the 873.8 *keV* state has been observed in the (α,xn) reaction [19].

5. *DISCUSSION*

The present study on the ^{81}Kr levels has established the properties of several, old as well as new, states in this nucleus. Thus, for some levels it has become possible to make meaningful comparison between experimental results and theoretical model predictions.

The Coriolis-coupling model [8], where last unpaired neutron at $1g_{9/2}$ shell is coupled to rotating core and Coriolis interaction is properly accounted for, correctly predicts the doublet of the states with $J^{\pi} = 7/2^+$ and $9/2^+$. Moreover, the $7/2^+$ state becomes the ground state of ^{81}Kr. Further, this calculation successfully predicts two low-lying levels with $J^{\pi} = 11/2^+$ and $5/2^+$ (at 800 and 1100 *keV*, respectively) which we observed at the excitation energy of 934.5 ($11/2^+$) and 1099.9 *keV* ($5/2^+$).

On the other hand, the level with $J^{\pi} = 5/2^+$ is predicted to occur between the levels of the doublet with $J^{\pi} = 7/2^+$ and $9/2^+$. Such a state has not been observed. But a more detailed comparison of the Coriolis-coupling model [8] with our experimental data is impossible as, to our knowledge, no calculation of the electromagnetic properties of ^{81}Kr levels has been performed. So, no definite conclusion about the deformation of the ^{81}Kr nucleus can be made. However, if the ^{81}Kr nucleus is deformed then the deformation must be positive (the prolate nucleus) as the comparison of the calculated [8] and the experimental states shows.

From another point of view, the first excited state at 49.5 *keV* ($9/2^+$) can be interpreted as a state whose main component is a $(n(1g_{9/2})^{-5}, \nu = 1)$ configuration (ν is the seniority number). Such interpretation is in accordance with (d,p) reaction data [14] and it enables to account for the structure of the ground state of $^{81}_{36}$Kr$_{45}$ with $J^{\pi} = 7/2^+$ which belongs to the family of anomalous coupling states.

There are two theories capable of explaining the structure of the excited states in ^{81}Kr, namely, the state at 49.5 *keV* of excitation energy. The first is Alaga's model [6] where a cluster of particles (or holes) is coupled to the vibrational field of the nucleus. The second, the model of Kuriyama et al. [7] is basicly the quasi-particle phonon coupling nodel [21] but it takes into account the phonon disassociation into a pair of the quasi-particles, one of which reassociates with the odd quasi-particle.

The experimental values of α_K (49.5 *keV*) $= 1.0 \pm 0.4$ and $\alpha_T = 0.76 \pm 0.30$ indicate the M1 multipolarity of the ground state transition with the maximum admixture of E2 equal 4%. It means that the ratio R of the probabilities of M1 transition to E2 transition is larger than 24.

In the framework of Alaga's model V.Paar [6] has calculated the B(M1) and B(E2) values for the $9/2^+ \rightarrow 7/2^+$ transition in nuclei with a number of protons P=47(Ag). If we suppose that similar calculation holds for nuclei with N 45 and 47 then Paar's values of reduced probabilities $B(M1) = 0.015 (n.m.)^2$ and $B(E2) = 0.11 (eb)^2$ [6] for the transition $9/2^+ \rightarrow 7/2^+$ enable us to calculate the ratio R. The calculation of ~R, using the known relationship between the probability of γ-transition and the reduced transition probability [22], gives R=100. Similar calculation of R was made with the values of $B(M1) = 4.5 (n.m.)^2$ and

$B(E2) = 13 \times 10^{-50} e^2 cm^4$ given by Kuriyama et al. /7/ for $7/2^+ \longrightarrow 9/2^+$ transition in $^{83}_{36}Kr_{47}$ nuclei. The value of $R = 20$ has been obtained.

On the basis of such a calculation the next conclusion about the structure of the anomalous coupling state with $J^\pi = 7/2^+$ can be drawn, namely, this state contains considerable amount of $|n(g_{9/2})^{-5}, 7/2, 0\,0>$, $|n(g_{9/2})^{-5}, 7/2, 12>$ and $|n(g_{9/2})^{-5}, 9/2, 12>$ configurations /6/ (the basis states are $|(1j)^{-5}, J, NR>$, where J is the angular momentum of the 5-hole cluster, N is the number and R is the angular momentum of phonons) or according to the Kuriyama's et al. language /7/, this state is created by the new type of collective excitations, the dressed n quasiparticle mode, $n(g_{9/2})^n$ with the seniority number $\nu = n$ ($n = 3, 5$).

The calculation of Kuriyama et al. /7/ predicts the excited levels of ^{81}Kr with the $J^\pi = 13/2^+$, $5/2^+$ and $11/2^+$ at the approximate energies of 1 *MeV*, 1 *MeV* and 1.5 *MeV*, respectively. It is remarkable that two levels with such quantum characteristics have been observed in the decay of $^{81m,g}Rb$, i.e., 934.5 ($11/2^+$) and 1099.9 ($5/2^+$).

Similarly as in the case of the ^{83}Sr nucleus /23/, some levels (548.9, 1014.4, 1099.9 and 1682.7 *keV*) are dominantly deexcited to the ground state with $J^\pi = 7/2^+$, whereas the levels from the second group (731.9, 873.8 and 934.5 *keV*) are mainly deexcited to the first excited state with $J^\pi = 9/2^+$. But it is necessary to add that this property of the levels is not so distinctive as in the case of the ^{83}Sr nucleus.

The large number of negative parity states populated in the decay of ^{81g}Rb give a possibility to do some conclusions about the validity of the Coriolis-coupling model /8/.

The relatively low logft values of the ^{81g}Rb β^+-decay to the levels of 190.4 (logft = 5.0), 636.7 (5.1), 701.0 (5.7), 994.2 (5.6), 1025.5 (5.8) and 1677.9 *keV* (5.4) excitation energies point at a similarity of the wave functions of these states (mainly $2p_{1/2}$ and $2p_{3/2}$ neutron hole states). The calculations of Heller and Friedman /8/ predict the states with $J^\pi = 3/2^-$, $5/2^-$ and $5/2^-$ at the excitation energy of 0.5 and 1.2 *MeV* above the $1/2^-$ state. They do not predict more $3/2^-$ states in the region of 0.8 MeV. However, our results suggest a possibility of the existence of more than one state with $J^\pi = 3/2^-$ which have the similar structure in the region of 0.5 - 1.0 *MeV* excitation energy.

The results of Paar's calculations /6/ show one more $3/2^-$ state at approximately 0.8 *MeV* excitation energy. Moreover, if we take his calculated values of the reduced probabilities $B(M1, 5/2^-_2 \to 3/2^-_1)$ and $B(E2, 5/2^-_2 \to 1/2^-)$ for the $5/2^-_2$ state at 994.2 *keV* excitation energy we are able to reproduce our experimental γ-ray branching ratio of 357.7 and 803.5 *keV* γ-transitions.

More detailed analysis of the decay modes of the excited levels with the negative parity is difficult because we cannot identify our levels with the levels of Paar's calculations unambiguously. But there is a hint that the excited states with $\pi = -1$ can be described as a neutron cluster coupled to the vibrating nucleus. The neutron cluster should be composed of the holes in the $g_{9/2}$, $p_{1/2}$ and $p_{3/2}$ shells.

In conclusion we summarize the following:

a) the negative parity states in ^{81}Kr seem to be mainly neutron hole states,

b) the wave function of the first excited state at 49.5 *keV* has a great amount of $|n(1g_{9/2})^{-5}, \nu = 1 >$ configuration,

c) at present no definite conclusion can be made on the validity of Alaga's /6/ or Kuriyama's /7/ model as no detailed theoretical calculation of properties of nuclei with $N = 45$ exists. However, if our extrapolation from $Z = 47$ to $N = 45$-47 is correct, then the Alaga's model is more appropriate,

d) the calculation of the electromagnetic properties of the excited states with $\pi = +1$ in the framework of the Coriolis-coupling model is needed to answer the question of the deformation of nuclei in the $1g_{9/2}$ shell.

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Table 1

Energies and relative intensities of γ-transitions from the $^{81m,g}Rb \rightarrow ^{81}Kr$ decay

	This work	Broda et al. a)	Waters et al. b)
Energy (keV)	Relative intensity		
	$T_{1/2}$ = 4.58 h		
49.5±0.1 c)	2.9± 0.7		
64.5±0.4	2.4± 0.5		
190.4±0.2	2760 ± 60	3500 ±200	2745 ±70
218.8±0.6	0.8± 0.2		
244.3±0.2	13.3± 0.4	16.7± 0.8	11.5± 1.3
266.2±0.5	1.6± 0.2		
283.1±0.5 d)	1.9± 0.4 d)		
319.5±0.4	1.9± 0.2		
339.4±0.4	2.5± 0.3		
357.7±0.2	32.6± 1.0	35.2± 1.7	28.9± 1.7
386.0±0.3	3.6± 0.4	19.7± 1.0	20.9± 3.8
389.0±0.2	19.6± 1.0		
399.7±0.5	1.1± 0.3		
446.3±0.1	1000 ± 30	1000	1000 ±19
456.9±0.1	130 ± 4	125.9± 7.2	116.2± 3.8
476.8±0.1	22.5± 0.6	21.0± 0.2	22.1± 2.6
499.4±0.2	5.1± 0.2	14.0± 4.0	
510.4±0.3 d)	230 ± 40 d)	110 ± 44 d)	2851 ±98
511 e)	2670 ±110	2880 ±150	
537.6±0.1	96.0± 6.6	95.1± 5.2	98.7± 2.6
537.6±1.0 d)	8 ± 3 d)		
548.9±0.1	20.3± 0.6	23.3± 1.2	17.9± 0.9
568.9±0.1	25.1± 0.7	21.8± 1.1	23.4± 0.9
602.3±0.3	2.2± 0.1	2.0± 0.3	0.4± 0.4
608.5±0.2	11.1± 0.5	10.4± 0.6	13.2± 0.4
689.9±0.3	1.3± 0.1		
701.5±0.5	2.3± 0.8 d)	2.0± 0.6	3.7± 0.3
729.1±0.1	12.7± 0.4	11.4± 0.6	12.3± 0.9
758.3±0.2	2.2± 0.1	2.3± 0.3	2.3± 0.2
782.5±0.5	0.6± 0.1		
803.5±0.2	35.9± 1.0	31.0± 1.5	33.6± 1.3
834.8±0.2	35.0± 1.0	32.2± 1.5	33.2± 1.3
903.2±0.6	0.2± 0.1		
912.5±0.6	0.2± 0.1		

Table 1 (continued)

This work		Broda et al.a)	Waters et al.b)
Energy (keV)	Relative	intensity	
968.4±0.9f)	<0.1	0.6±0.2	
977.1±0.2	24.3±0.8	20.1±1.2	20.8±2.0
1041.1±0.2	23.0±1.3	21.6±1.2	21.3±0.8
1048.4±0.3	2.0±0.2		
1069.3±0.3	2.6±0.1	2.8±0.2	2.8±0.7
1087.7±0.5	0.3±0.1	0.9±0.2	1.2±0.4
1090.4±0.5	0.5±0.1		
1108.0±0.2	2.2±0.1	1.4±0.3	2.7±0.3
1136.4±0.4	0.5±0.1		
1363.8±0.6	0.2±0.1		
1381.5±0.5	0.4±0.1		
1427.8±0.2	1.4±0.1	1.4±0.3	1.8±0.3
1487.4±0.5	0.4±0.2		
1536.0±0.8	0.2±0.1		
1554.9±0.3	1.8±0.2		1.8±0.2
1874.0±0.4	0.6±0.1		

$T_{1/2}$ = 30.25 min

Energy (keV)	Relative intensity	Energy (keV)	Relative intensity
49.5±0.1	660 ± 35	682.3±0.1	42.0±1.8
86.2±0.2g)	4630 ±200	729.2±0.8d)	28 ±2
190.4±0.2h)	12.1± 1.2i)	732.1±0.2	18 ±1
266.2±0.5h)	~0.1 i)	761.9±0.2	8.0±0.6
368.3±0.3	9.2± 0.5	824.2±0.5	13 ±1
446.3±0.1h)	18.0± 2.0i)	873.8±0.3	7.7±0.6
456.9±0.1h)	7.4± 1.4i)	885.0±0.2	32.7±1.4
463.3±0.3	18.0± 2.0	932.4±0.2	32.7±1.4
465.5±0.3	18.0± 2.0	981.6±0.2	24.9±1.4
499.4±0.2	25.0± 1.5	1011 ±1	≲3
511 e)	1810 ±100	1014.4±0.4	10.3±0.7
548.9±0.1	90.0± 5.5	1087 ±1	10.2±1.5
551.5±1.5d)	5 ± 2 d)	1099.9±0.2	64.2±2.7
643.6±0.1	98.4± 4.2	1136 ±1	3.6±0.7
643.6±1.5d)	1.6± 0.8d)	1157.0±0.4	6.0±0.6
657.5±0.2	11.7± 0.5	1194.6±0.2	94.5±3.5

Table 1 (continued)

Energy (keV)	Relative intensity	Energy (keV)	Relative intensity
1206.0±1.5	≤1	1694.4±0.4	15.6±0.8
1286.9±0.4	5.9±0.4	1732 ±1	~1
1297.0±0.4	6.3±0.4	1743.5±0.3	48.4±2.1
1633.2±0.5	6.0±0.4	1781.8±0.5	4.7±0.4
1638.4±0.4	10.8±0.7	1853 ±1	0.9±0.2
1682.7±0.4	13.1±0.8	1902.6±0.7	4.1±0.4
1687.9±0.4	9.1±0.7		

a) Ref. 1).

b) Ref. 2).

c) Value determined from the decay of ^{81m}Rb.

d) Values determined on the basis of γ-γ coincidence measurements.

e) The annihilation peak.

f) Published by Broda et al.1) only.

g) The isomeric transition of ^{81}Rb.

h) Values determined from the decay of ^{81g}Rb.

i) The intensity have been determined from the γ-γ coincidence measurements and the level scheme.

Table 2

Results of γ-ray coincidence measurements associated with the decay of ^{81m,g}Rb.

Energy (keV)	Intensity exp.	Intensity calc.	Energy (keV)	Intensity exp.	Intensity calc.
			$T_{1/2}$ 4.58 h		
			Gate 244.3 keV		
266.2	Y	0.2	537.6	0.7	0.5
456.9	11	13.1	977.1	1.3	1.4
			Gate 357.7 keV		
446.3	29.2	32.6			

Table 2 (continued)

Energy (keV)	Intensity exp.	Intensity calc.	Energy (keV)	Intensity exp.	Intensity calc.
Gate 729.1 keV					
319.5	1.8	1.7	758.3	1.9	1.8
399.7	0.7	1.0			
Gate 758.3 keV					
729.1	1.4	1.8			
Gate 977.1 keV					
244.3	1.3		510.4	23	
456.9	1.2				
Gate 1041.1 keV					
446.3	24.8	23.0			
Gate 1069.3 keV					
608.5	2.6	2.6			
Gate 1108.0 keV					
446.3	1.9	2.2			
Gate 1427.8 keV					
446.3	1.3	1.4			
$T_{1/2}$ = 30.25 min					
Gate 49.5 keV					
368.3	Y		1157.0	Y	
499.4	Y		1194.6	Y	
682.3	Y		1633.2	Y	
885.0	Y		1638.4	Y	
932.4	Y		1694.4	Y	
Gate 446.3 keV					
463.3	14	18	643.6	18	18
Gate 456.9 keV					
643.6	3.4		1286.9	4	5.9
Gate (548.9 + 551.5) keV					
465.5	10		657.5	8.8	9.1
548.9	4		729.2	12	
551.5	5		1194.6	70	73.5
643.6	11				

Table 2 (continued)

Energy (keV)	Intensity exp.	Intensity calc.	Energy (keV)	Intensity exp.	Intensity calc.
Gate 643.6 keV					
368.3	6.4	9.2	551.5	6	
446.3	18.5	18.0	643.6	2.6	
456.9	3.5		682.3	6.6	6.4
463.3	15	18.0	732.1	4.4	2.8
548.9	4		1099.9	64.2[a]	64.2[a]
Gate 657.5 keV					
499.4	3.2	2.6	548.9	7.0	9.1
Gate 682.3 keV					
49.5	Y		643.6	4.3	6.4
368.3	4.9	6.4			
Gate(729.2 + 732.1) keV					
465.5	10		643.6	4	2.8
548.9	8		1014.4	10	10.3
Gate 761.9 keV					
932.4	9	4.5	981.6	4.2	3.5
Gate 885.0 keV					
49.5	Y				
Gate 932.4 keV					
49.5	Y		761.9	4	4.5
Gate 981.6 keV					
761.9	Y				
Gate 1099.9 keV					
643.6	60	64.2			
Gate 1194.6 keV					
49.5	Y		548.9	73	73.5
499.4	16	20			
Gate 1286.9 keV					
456.9	8	5.9			

Y = coincidence

[a]) Intensities normalized.

Table 2 (continued)

Energy	Intensity		Energy	Intensity	
(keV)	exp.	calc.	(keV)	exp.	calc.
Gate 386.0 keV					
608.5	3.1	3.6			
Gate 389.0 keV					
446.3	19.2	19.6			
Gate 446.3 keV					
64.5	Y	2.4	602.3	2.1	2.2
283.1	1.9		701.5	2.3	
319.5	Y	0.25	977.1	0.9	
339.4	3.2	2.5	1041.1	25.7	23.0
357.7	32.6a)	32.6a)	1108.0	2.5	2.2
389.0	20.6	19.6	1427.8	1.2	1.4
Gate 456.9 keV					
244.3	11.5	13.1	782.5	0.6	0.5
537.6	92	95	977.1	1.8	1.4
568.9	25.8	24.7			
Gate 476.8 keV					
49.5	Y	2.3	548.9	17.2	17.5
499.4	5.0	4.9			
Gate 537.6 keV					
244.3	0.4		456.9	96	95
266.2	1.3	1.2			
Gate 548.9 keV					
476.8	16.5	17.5	689.9	1.0	1.0
Gate 568.9 keV					
266.2	0.6	0.3	456.9	24.8	24.8
Gate 602.3 keV					
446.3	1.5	2.2			
Gate 608.5 keV					
386.0	3.3	3.6	1136.4	Y	0.5
1069.3	2.2	2.6			
Gate 689.9 keV					
499.4	0.3	0.26	548.9	1.2	1.0

Table 3

Internal conversion coefficients for γ-transitions in ^{81}Kr.

E_γ [keV]	γ-ray relative intensity	Normalized $I_e \times 10^2$	Experimental value $\alpha_K \times 10^3$	Theoretical $\alpha_K \times 10^3$ value[a]			Deduced multipolarity
				E1	M1	E2	
49.5	2.9 ± 0.7	300 ± 10	1000 ± 400	580	860	9400	M1+<6% E2
64.5	2.4 ± 0.5	95 ± 9	400 ± 100	260	410	3800	M1+<3% E2
244.3	13.3 ± 0.4	26 ± 2	20 ± 3	5.6	11	31	M1 + E2
357.7	32.6 ± 1.0	14 ± 4	4.3 ± 1.3	2.0	4.4	8.4	M1
389.0	19.6 ± 1.0	7.2 ± 2.3	3.7 ± 1.2	1.6	3.4	6.2	M1
446.3	1000	240[b]	2.4[c]		2.4		M1[b]
456.9	130 ± 4	16 ± 4	1.2 ± 0.4	1.1	2.3	3.6	E1
510.4	230 ± 40	51 ± 7	2.2 ± 0.6	0.82	1.8	2.7	M1 , E2
537.6	96 ± 7	20 ± 4	2.1 ± 0.6	0.78	1.6	2.25	E2 , M1
548.9	20.3 ± 0.6	4.6 ± 0.9	2.2 ± 0.6	0.7	1.47	2.1	M1 , E2
568.9	25.1 ± 0.7	3.4 ± 1.0	1.3 ± 0.5	0.65	1.35	1.84	M1 , E2
803.5	35.9 ± 1.0	2.5 ± 1.0	0.70 ± 0.28	0.29	0.62	0.76	M1 , E2
834.8	35.0 ± 1.0	2.2 ± 1.0	0.61 ± 0.29	0.27	0.56	0.68	M1 , E2

[a] From ref. 16).

[b] Assumed value for normalization.

[c] Theoretical α_K value for M1 multipolarity.

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