ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
Дубна

E6 - 6809

K.-H.Kaun, W.Neubert, W.Schulze, F.Stary,
Yu.N.Rakivnenko, A.P.Klyucharev, V.A.Lutsik,
E.A.Skakun, I.A.Romaniy,
L.K.Peker, E.I.Volmyanski

A HIGH-SPIN ISOMER IN ^{204}Bi

E6 - 6809

K.-H.Kaun, W.Neubert, W.Schulze, F.Stary,
Yu.N.Rakivnenko[1], A.P.Klyucharev[1], V.A.Lutsik[1],
E.A.Skakun[1], I.A.Romaniy[1],
L.K.Peker[2], E.I.Volmyanski[2]

A HIGH-SPIN ISOMER IN ^{204}Bi

Submitted to *Physics Letters*

[1] Physico-Technical Institute of the Ukrainian Academy of Sciences, Kharkov, USSR

[2] Institute of Metrology, Leningrad, USSR

Каун К., Нойберт В., Шульце В., Стары Ф., Ракивненко Ю.Н., Ключарев А.П., Луцик В.А., Скакун Е.А., Романий И.А., Пекер Л.К., Волмянский Э.И.

E6 - 6809

Изомерное состояние с высоким спином в ядре ^{204}Bi

В ядре ^{204}Bi было найдено изомерное состояние с периодом полураспада $T_{1/2}$ = 1,1 мсек и со спином $I^{\pi} = 16^{+}$, используя реакции с тяжелыми ионами и α-частицами. Это состояние описывается четырехквазичастичной конфигурацией $\pi(h_{9/2})^{1}\nu(f_{5/2})^{-1}\nu(i_{13/2})^{-2}$.

Препринт Объединенного института ядерных исследований.
Дубна, 1972

Kaun K.-H, Neubert W., Schulze W., Stary F., Rakivnenko Yu.N., Klyucharev A.P., Lutsik V.A., Skakun E.A., Romaniy I.A., Peker L.K., Volmyanski E.I

E6 - 6809

A High-Spin Isomer in ^{204}Bi

By making use of heavy ion and alpha particle induced reactions an isomeric state was found in the ^{204}Bi nucleus, which has a half-life of $T_{1/2}$ = 1.1 ms and the quantum characteristics $I^{\pi} = 16^{+}$. The four-quasi-particle configuration $\nu(i_{13/2})^{-2}\nu(f_{5/2})^{-1}\pi(h_{9/2})^{1}$ has been ascribed to this state.

Preprint. Joint Institute for Nuclear Research.
Dubna, 1972

From earlier investigations of isomers in the doubly odd Bi nuclei with $A = 198$, 200, 204, 206 and 208 two-quasiparticle isomers with the characteristics $I^{\pi} = 10^{-}$ are known /1,2,3/, which have the configuration $\pi(h_{9/2})^{1}\nu(i_{13/2})^{-1}$. In ^{204}Bi this state has a half-life of $T_{1/2} = 13$ ms and an excitation energy of 808 keV. Further investigations at the heavy ion cyclotron U-300 of the Joint Institute for Nuclear Research in Dubna and with α-particles at the linear accelerator of the Physico-Technical Institute in Kharkov showed that another isomeric state exists in ^{204}Bi which has an excitation energy of 2795 keV and a half-life of $T_{1/2} = 1.1$ ms. This second isomeric state was excited by the reactions $^{198}Pt(^{11}B,5n)\,^{204}Bi$ and $^{203}Tl(\alpha,3n)\,^{204}Bi$. In both cases metallic targets, enriched to more than 90% were used. In Dubna the prompt and delayed gamma ray spectra and lifetimes were measured with Ge(Li) detectors. In Kharkov the conversion electron spectra, the lifetimes and excitation functions of the delayed transitions were recorded with an ironfree magnetic spectrometer /4/. The threshold for the excitation of the 1.1 ms isomer lies about 2 MeV higher than the threshold for the 13 ms isomer, also populated in the $^{203}Tl(\alpha,3n)\,^{204}Bi$ reaction, which indicates, that this state has a high excitation energy and high angular momentum. A detailed description of the experimental technique, the obtained spectra and the analysis of the experimental results is given in a forthcoming paper. In table 1 the experimental results on energies, relative gamma ray and conversion electron intensities and the intensity ratios of the transitions in the prompt and delayed spectra are summarized. In addition the experimentally determined conversion coefficients and the multipole order deduced from them are presented.

Figure 1 shows the decay scheme of the 1.1 ms isomer in ^{204}Bi. The deexcitation takes place by a stretched cascade to the 10^{-} isomeric state, which leads to the conclusion, that the spin and parity values $I^\pi = 16^+$ are to be ascribed to the 1.1 ms isomer. The stretched cascade deexcitation may be concluded from the fact, that within the experimental errors nearly the same transition intensity was found for each delayed transition, listed in table 1. The sequence of the transitions was deduced from the comparison of the relative gamma ray intensities of the prompt and delayed spectra (table 1, column 3). From this comparison and the experimentally obtained multipole order the 182 keV transition is suggested to be the isomeric transition. Our data do not unambiguously determine the 93 keV - 736.5 keV sequence, but the fact that they are of nearly equal intensity indicates that they arise from states of approximately equal energy and not from states of 736.5 keV energy difference as the reverse level sequence would suggest. The proposed position of the 1.1 ms isomer is particularly confirmed by the fact, that the threshold for exciting the 1.1 ms isomer is more than 2 MeV higher than the threshold for exciting the 10^- isomer. The existence of a stretched cascade without further branching gamma transitions indicates a monotonously increasing or decreasing spin sequence. A decreasing sequence can be excluded, since otherwise delayed transitions should be observed, which do not belong to the cascade, such as the direct deexcitation of the 1.1 ms isomer to the low lying states of ^{204}Bi. The deexcitation of the 1.1 ms isomer by the observed cascade with increasing spin directly to the ground state is excluded because no branching transitions to the 10^- isomeric state were observed. If we assume decreasing spin sequence, an $I^\pi = 0^-$ assigment for the isomeric state and feeding in the ^{204}Po gr.st. decay are to be expected. However, no γ-transition observed in the $^{204}Po \rightarrow {}^{204}Bi$ decay corresponds to our γ-transitions in table 1.

On the basis of these arguments the level scheme of fig. 1 was established. The high spin value $I^\pi = 16^+$ of the 1.1 ms isomeric state cannot be explained by any two-quasiparticle configuration, because the coupling of two $i_{13/2}$ particles results in a maximum spin value $I = 12$. Therefore, we conclude that the structure of this state is more complex. By comparing this structure with the adjacent even-even core ^{202}Pb we find, that an angular momentum $I^\pi = 16^+$ can arise from two-neutron states $[\nu(i_{13/2})^{-1}\ \nu(p_{3/2})^{-1}]_{5^-}$ $[\nu(i_{13/2})^{-1}\ \nu(p_{1/2})^{-1}]_{7^-}$ or $[\nu(i_{13/2})^{-1}\nu(f_{5/2})^{-1}]_{9^-}$ coupled to the $[\pi(h_{9/2})^1\ \nu(i_{13/2})^{-1}]$ configuration, which is responsible for the 10^- isomer in the doubly-odd Bi nuclei. In order to find out the structure of the highly excited isomeric state in ^{204}Bi we calculated the matrix elements of the four-particle configuration

$$\langle \pi(h_{9/2})^1 \nu_1 (j)^{-1} J_{12}, \nu_{23} (i_{13/2})^{-2} J_3 ; I | \sum_{i<k} V_{ik} | \pi(h_{9/2})^1 \nu_1 (j)^{-1} J_{12}, \nu_{23} (i_{13/2})^{-2} J_3 ; I \rangle$$

for residual interactions V_{ik} of the Wigner, singlet and tensor type. In place of j we used a $f_{5/2}$, $p_{3/2}$ or $p_{1/2}$ neutron hole. The Wigner force is mainly responsible for the splitting of the multiplet, as shown in Fig. 2. An addition of singlet and tensor forces does not change the level ordering essentially. We calculated the matrix elements for both the configurations

$$\pi(h_{9/2})^1 \nu_1 (f_{5/2})^{-1} J_{12} = 4,5,6,7 \quad \nu_{23} (i_{13/2})^{-2} J_3 = 10,12$$

and

$$\pi(h_{9/2})^1 \nu_1 (p_{3/2})^{-1} J_{12} = 3,4,5,6 \quad \nu_{23} (i_{13/2})^{-2} J_3 = 10,12$$

using oscillator wave functions. For the indicated values J_{12} and J_3 the diagonalization was carried out for the first configuration. In this case the calculated matrix elements and also the result of the diagonalization show that the lowest-lying level has maximum angular momentum, provided $J_{12} = J_{12\,max} = 7$ and $J_3 = J_{3\,max} = 12$. For the second configuration we get the same result, namely $J_{12} = J_{12\,max} = 6$ and $J_3 = J_{3\,max} = 12$. From the calculated multiplet splitting shown in Fig. 2 we deduced that the levels with $11^+ \leq I^\pi \leq 16^+$ can be isomeric. If, however, $(f_{5/2})^{-1}$ or $(p_{3/2})^{-1}$ are replaced by a $p_{1/2}$ neutron hole, we obtain $12^+ \leq I^\pi \leq 15^+$ as possible spin values of the isomeric state. This leads to the conclusion that in the above mentioned four-particle configuration an $f_{5/2}$ or $p_{3/2}$ neutron hole is responsible for the observed isomerism in ^{204}Bi. Our results on the decay of the high spin isomer in ^{200}Bi (ref. 5) favour the configuration $\pi(h_{9/2})^1 \nu_1 (f_{5/2})^{-1} \nu_{23} (i_{13/2})^{-2}$.

References

1. M.Bonitz, J.Kantele, N.J.S.Hansen. Nucl.Phys., A115, 219 (1968).
2. Yu.N.Rakivnenko et al. Ukr.Fiz.Journ., 17, 1037 (1972).
3. U.Hagemann et al. JINR Preprint, E6-6597, Dubna (1972).
4. Yu.N.Rakivnenko et al. Ukr.Fiz.Journ., 13, 478 (1968).
5. K.-H.Kaun, W.Neubert et al. JINR Preprint, E6-6808, Dubna (1972).

Received by Publishing Department
on November 21, 1972.

Table 1
Transition energies, relative intensities of the γ-ray and conversion electron lines of the delayed transitions, outgoing from the 1.1 ms isomer in ^{204}Bi

E_γ(keV)	I_γ(%)	Prompt to delayed intensity ratio	I_e(%)	Experimental conversion coefficients	Multipole order
93 ± 1	10 ± 2	0.6	344(L)	$\alpha_L \approx 2.4$	M1
182 ± 1	13 ± 2	0.3	1325 ± 60 (K)	$\alpha_K = 7.2 \pm 1.4(0)$	M2
367 ± 1	95 ± 5	0.8	378 ± 20 (K)	$\alpha_K = 2.8 \pm 0.3(-1)$	M1
608 ± 1	100 ± 5	1.0	100(K)	$\alpha_K = 7.1 \pm 0.7(-2)$	M1
736.5 ± 0.8	91 ± 5	0.5	47.5 ± 4.0(K)	$\alpha_K = 3.7 \pm 1.9(-2)$	M1

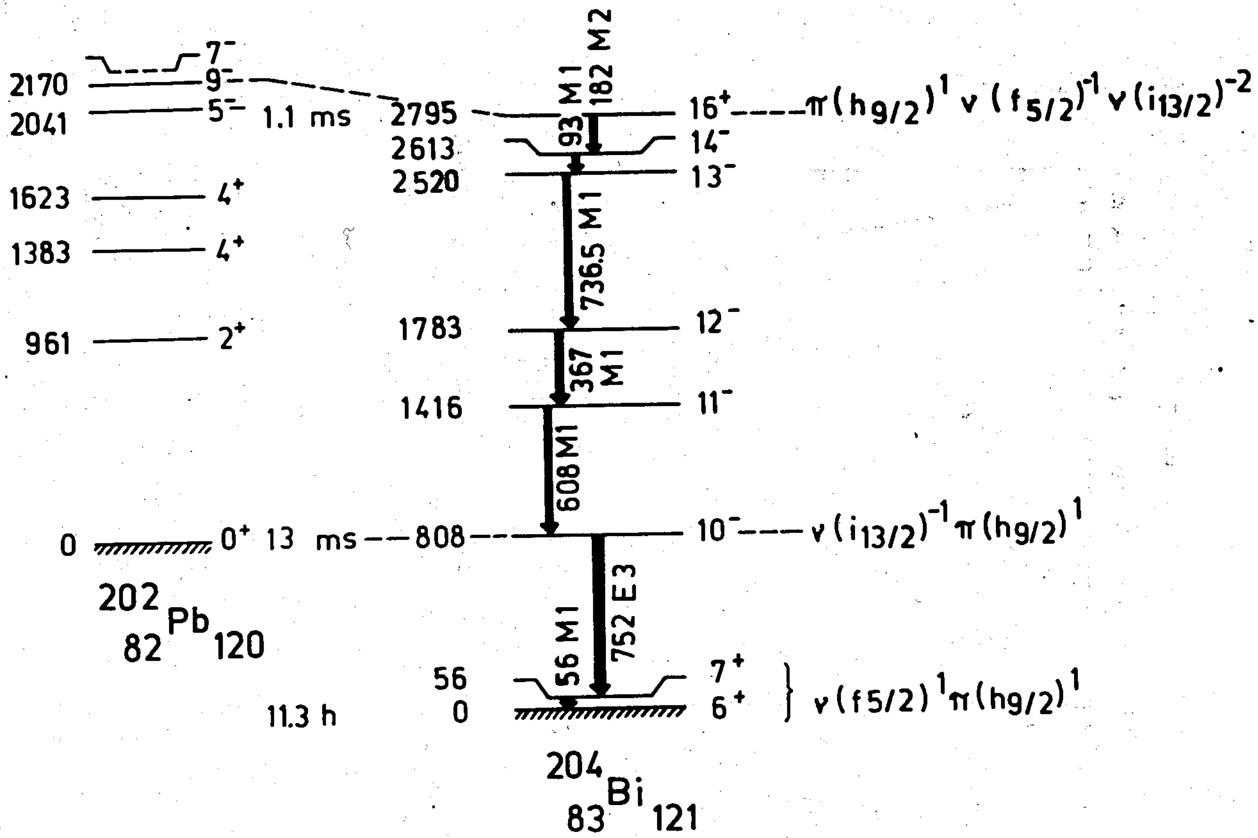

Fig. 1. Decay scheme of the 1.1 ms isomer in ^{204}Bi

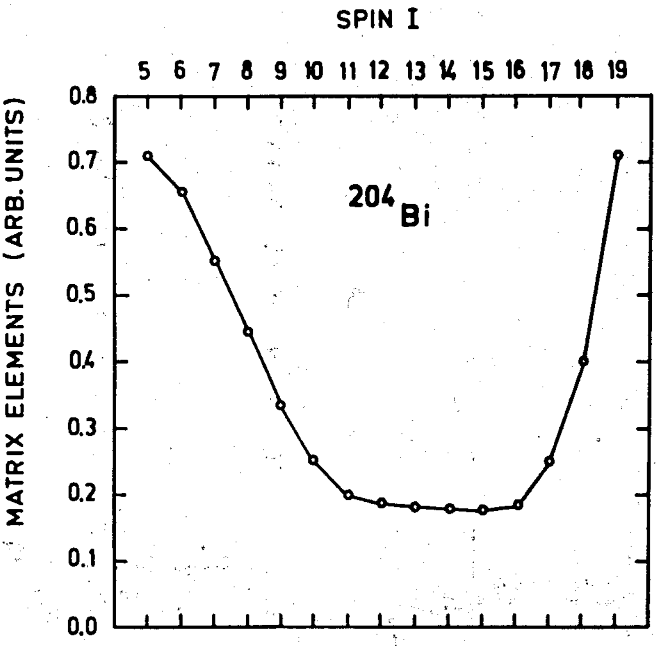

Fig. 2. Matrix elements for the level splitting of the multiplet $[\pi(h_{9/2})^1\ \nu(f_{5/2})^{-1}\ J_{12} = 7,\ \nu(i_{13/2})^{-2}\ J_3 = 12]$