

LONG-LIVED POSITIVE PARITY ISOMER IN  $^{76}\text{Br}^{\star}$

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A  $4^+$ , 1.3 s isomer has been found at 102.6 keV in  $^{76}\text{Br}$  using the  $^{75}\text{As}(\alpha, 3n)$  reaction. A previously reported band structure is interpreted to decay into this isomer of probable  $\tilde{\pi}_{g_{9/2}} \otimes \tilde{\nu}_{g_{9/2}}$  parentage.

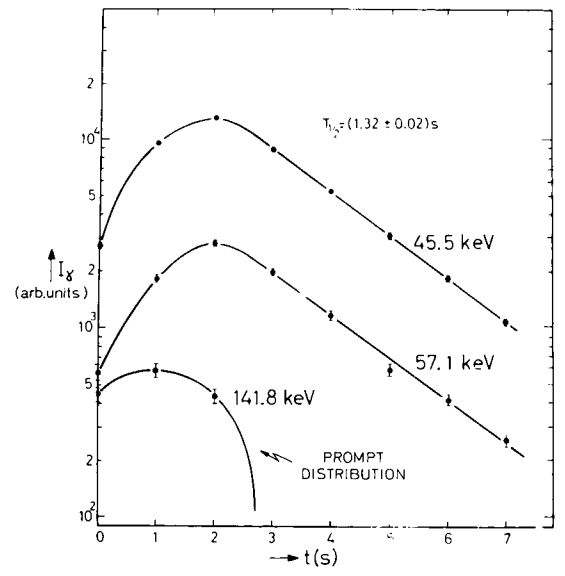
In a recent study [1] of the  $^{75}\text{As}(\alpha, 3n)$  reaction a collective band was found in  $^{76}\text{Br}$  which not only shows deviations from a rigid-rotor behaviour similar to those previously observed [2] for the  $5/2^+$  ground-state band of the neighboring  $^{77}\text{Kr}$ , but the excitation energies of the lowest states in the two bands are very nearly the same. This unexpected parallelism prompted speculation [1] that the unpaired proton in  $^{76}\text{Br}$  might be in a decoupled state.

However, an analysis [3] carried out in terms of the two-quasiparticle-plus-rotor model [4], shows that these features are difficult to understand for a band built on a low-spin state such as the  $1^-$  ground state in  $^{76}\text{Br}$ . On the other hand, one has the experimental information that in  $^{77}\text{Br}$  a  $9/2^+$  decoupled band appears at 106.2 keV [5], which suggests the possible relevance of the positive parity proton states in this connection.

In addition Lueders et al. [6] recently studied  $^{76}\text{Br}$  by means of the  $^{76}\text{Se}(p, \gamma)$  reaction and since they do not observe the band they argue that this band might be built on an unknown high-spin excited state.

In view of these facts it became tempting to search for a low-lying isomer in  $^{76}\text{Br}$  and such was the objective of the present work.

The search was undertaken in the ms and s region using a mechanical chopper to pulse the  $\alpha$ -particle beam from the Buenos Aires Synchrocyclotron. Levels of  $^{76}\text{Br}$  were reached, as in the previous work, through the  $^{75}\text{As}(\alpha, 3n)$  reaction.



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Fig. 1. Time distributions of the  $\gamma$ -ray intensity for the 45.5, 57.1 and 141.8 keV transition. The latter line is the first transition in the  $\Delta I = 1$  collective cascade in  $^{76}\text{Br}$  (see ref. [1]) and has a prompt distribution.

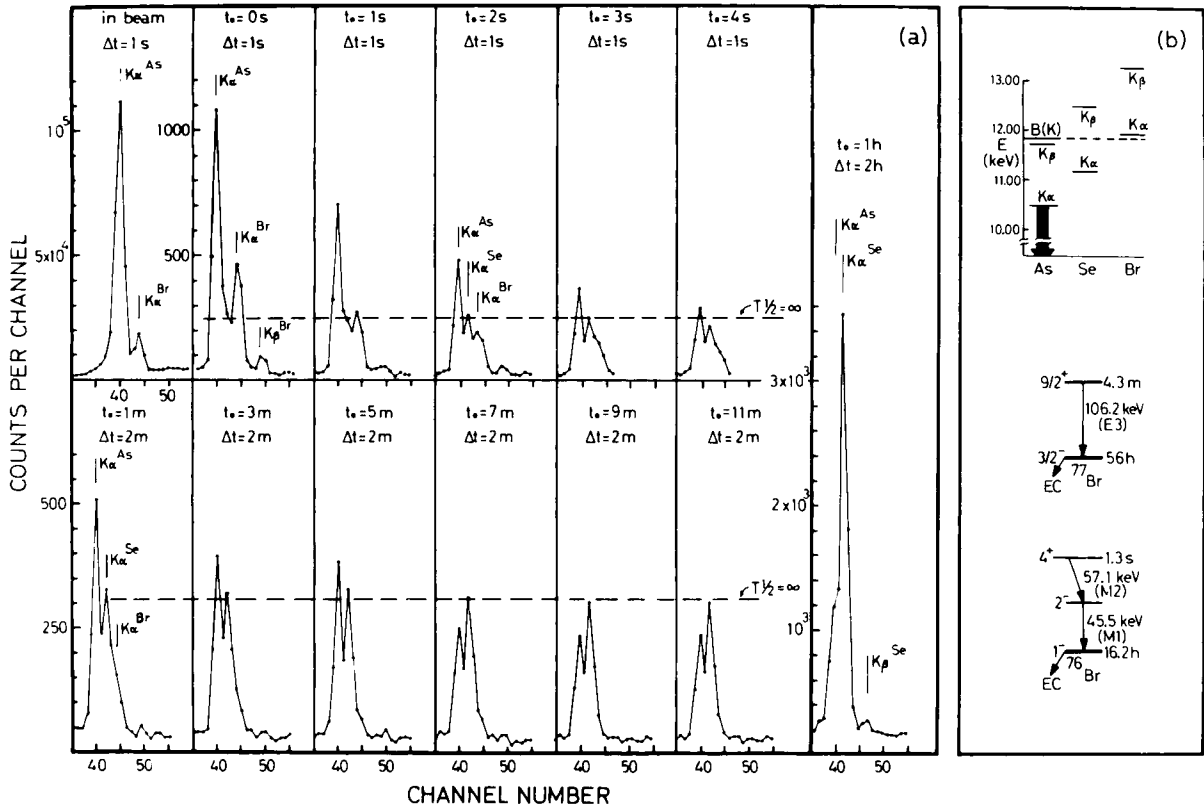


Fig. 2. (a) K X-ray spectra accompanying the decay of the 1.3 s isomer in  $^{76}\text{Br}$  (upper part), of the  $9/2^+$  state in  $^{77}\text{Br}$  [5] (lower part) and of the  $^{76}\text{Br}$  ground state through electron capture to  $^{76}\text{Se}$  (right-hand side). The starting time and time interval at which each spectrum was measured are denoted  $t_0$  and  $\Delta t$ , respectively. (b)  $\text{K}\alpha$  and  $\text{K}\beta$  transition energies for As, Se and Br and their relation to the K-shell binding in As ( $B(K)$ ) (top), decay scheme for the  $9/2^+$  state in  $^{77}\text{Br}$  and new partial level scheme for  $^{76}\text{Br}$  proposed in the present work.

Two lines of 45.5 and 57.1 keV were found to decay with a half-life of  $1.32 \pm 0.02$  s (see fig. 1). These lines are identified with  $^{76}\text{Br}$  because, (a) there is Br K X-ray characteristic radiation which decays with the same half-life, and (b) the mass number  $A = 76$  is established by their excitation functions. Fig. 2 shows that there is As K X-ray intensity present which also disappears with  $T_{1/2} \approx 1.3$  s (see upper part of fig. 2a). The reason for this can be found in the upper part of fig. 2b. The Br  $\text{K}\alpha$  energy is only slightly larger than the K-shell binding  $B(K)$  of As, resulting in a very efficient fluorescence effect in the target matrix. The same phenomenon can be observed in the lower part of fig. 2a for the As fluorescence radiation produced by the conversion X-rays originating in the decay of the 4.3 min isomer in  $^{77}\text{Br}$  through the 106.2 keV E3  $\gamma$ -ray

(fig. 2b). In fact the study of the intensity relationships in this decay of known multipolarity has allowed us to calibrate the target material in its ability to convert Br K X-radiation into As K X-rays, and hence to obtain the conversion coefficient of the isomeric transition. A further correction must be made owing to the Se-induced fluorescence since  $\text{K}\beta(\text{Se}) > B(K)$ . This can be easily computed from the long-lived activity spectrum (see X-ray spectrum for  $t_0 = 1$  h in fig. 2a).

The 45.5 keV line is most likely the  $(2^-, 0^-) \rightarrow 1^-$  M1 ground-state transition seen in the  $^{76}\text{Kr}$  decay [7,8] and  $(p, \gamma)$  reaction [6] studies. It is the most intense line among those assigned here to  $^{76}\text{Br}$  and its total intensity compares well with the total collected intensity of the 559.1 keV  $2^+ \rightarrow 0^+$  ground-state transition in  $^{76}\text{Se}$  fed from the decay of the 16.2 h ground

Table 1  
Intensity balance and conversion coefficients in the decay of the  $^{76}\text{Br}$  isomer.

$E_\gamma$ (keV)	Identification	Character	$I_T$	$\alpha_K$		$\alpha_{\text{tot}}$	
				Theor.	Exp.	Theor.	Exp.
45.5	$2^- \rightarrow 1^-, ^{76}\text{Br}$	M1	$8.7 \pm 0.2^{\text{a}}$ $9.3 \pm 0.6$	0.96		1.06	
57.1	$4^+ \rightarrow 2, ^{76}\text{Br}$	M2	$8.9 \pm 0.3$ $6.6 \pm 0.3$	8.23	$10.5 \pm 3^{\text{b}}$	9.78	$9.5 \pm 0.5^{\text{c}}$
559.1	$2^+ \rightarrow 0^+, ^{76}\text{Se}$	E2	$10.0 \pm 0.6$			6.96	

a) Delayed component. b) Assuming  $\alpha_K^{\text{th}}(\text{M1})$  for the 45.5 keV transition. c) From the  $I_T^{\text{del}}(45) = I_T(57)$  condition.

state of  $^{76}\text{Br}$  (see table 1). The decay constants of the 45.5 and 57.1 keV  $\gamma$ -rays are equal and since (a) the 57.1 keV line is not seen in the (p, n $\gamma$ ) experiment [6] (which only populates states with  $I \leq 2$ ) nor in the decay work [7,8], (b) it is in coincidence with the 45.5 keV line, and (c) there are no other observed lines decaying with  $T_{1/2} \approx 1.3$  s, we conclude that the 57.1 keV  $\gamma$ -ray depopulates a high-spin state feeding the first excited state at 45.5 keV. The  $\gamma$ -intensity difference between these two lines may thus be explained by a higher multipolarity for the 57.1 keV  $\gamma$ -ray giving rise to isomerism. In this case the total transition intensity associated with the 57.1 keV  $\gamma$ -ray has to be equal to the total transition intensity of the delayed component of the 45.5 keV  $\gamma$ -ray. As shown in table 1 M2 multipolarity turns out to be the only possibility compatible with the data. This multipolarity is fully consistent with the measurement of the K-shell conversion coefficient obtained as outlined above.

All these data lead us to the conclusion that the 1.3 s isomer in  $^{76}\text{Br}$  corresponds to a  $4^+$  state at 102.6 keV depopulating into the  $2^-$  first excited state at 45.5 keV (bottom of fig. 2b). It is thus possible that the previously reported  $\Delta I = 1$  band in  $^{76}\text{Br}$  is built on this  $4^+$  isomer rather than on the  $1^-$  ground state [1], providing an explanation for the non-observation of the corresponding  $\gamma$ -lines in the (p, n $\gamma$ ) reaction work [6].

Indeed, one may expect low-lying high-spin positive parity states of  $\tilde{\nu}g_{9/2} \otimes \tilde{\pi}g_{9/2}$  parentage in this region of the periodic table; the neutron Fermi surface is known to lie within the Nilsson multiplet originated in the  $g_{9/2}$  orbit as revealed by the spectrum of the neighboring isotope  $^{77}\text{Kr}$  [2] and the odd-proton nuclei exhibit low-lying  $9/2^+$  isomeric states on top of which decoupled bands develop (such as  $^{77}\text{Br}$  [5],

$^{65}\text{Ga}$  [9],  $^{65}\text{Zn}$  [9] and  $^{81}\text{Rb}$  [10]). It is interesting to note that the excitation energy of the  $I^\pi = 4^+$  isomer reported here coincides remarkably well with the  $9/2^+$  band head energy in  $^{77}\text{Br}$ . Moreover, the high- $j$  and unique parity character of both neutron and proton excitations makes it plausible to expect large Coriolis distortions, particularly considering the decoupled character of the proton, resembling the situation of the "semidecoupled" bands found in doubly odd Tl isotopes [4] and allowing a description [3] of the intriguing parallelism between  $^{76}\text{Br}$  and  $^{77}\text{Kr}$ .

Finally, it should be mentioned that in more recent work [11] a collective band similar to that in  $^{76}\text{Br}$  has been reported in  $^{78}\text{Rb}$ , which is most likely built on an  $I = 4$  isomeric state. However, the parity of this isomer is still an open question.

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