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1973 J. Phys. A: Math. Nucl. Gen. 6 L133

(http://iopscience.iop.org/0301-0015/6/9/003)

J. Phys. A: Math., Nucl. Gen., Vol. 6, September 1973. Printed in Great Britain. © 1973

LETTER TO THE EDITOR

The decay of ^{108m}In

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Received 27 July 1973

Abstract. The gamma rays emitted in the β^+/EC decay of 59 min ^{108m}In and 40 min ^{108}In have been studied with Ge(Li) detectors in singles and coincidence. A decay scheme for ^{108m}In has been established. The results indicate that ^{108m}In has spin and parity 5^+ or 6^+. This is discussed in terms of the *j–j* coupling model.

Two states in ^{108}In are known to β^+/EC decay to levels in ^{108}Cd with half-lives of 40 and 59 min. These two states are assigned spins of 2^+ or 3^+ and 6^+ or 7^+ respectively in the only published decay scheme for ^{108}In (Katoh *et al* 1962). The purpose of the present work was to study the decay of ^{108m}In, the high spin isomer of 59 min half-life, in order to obtain some information about high spin states in ^{108}Cd and check the spin of ^{108m}In. The level ordering in odd–odd nuclei is sensitive to the residual proton–neutron interaction (De Shalit and Walecka 1961). In ^{108}In the low-lying states arise from $(\pi g\, 9/2)^{-1}\, (\nu d\, 5/2)^{-3}$ configuration, and a knowledge of the level ordering within this multiplet is of importance in determining the strength of the residual interaction.

In order to assign gamma rays to ^{108}In and ^{108m}In, sources containing widely different proportions of the two activities were produced by the ^{108}Cd(p,n)^{108}In, ^{107}Ag(^{3}He,2n)^{108}In and ^{94}Mo(^{16}O,np)^{108}In reactions. The singles gamma ray spectrum from each of these sources was studied with Ge(Li) detectors and the energies, relative intensities and half-lives of the observed gamma rays were measured. Table 1 lists the energies and relative intensities of the gamma rays assigned to ^{108m}In in the present work and compares them with the same quantities as reported by Didorenko *et al* (1970). In general where a gamma ray is reported in both experiments the agreement is good. Gamma–gamma coincidences with Ge(Li) detectors were recorded in an event-by-event mode on magnetic tapes for both the (p,n)- and (^{3}He,2n)- induced activities. The results obtained from spectra in coincidence with individual gamma rays, which were reconstructed off-line, are summarized in table 2.

These coincidence relationships together with the measured relative intensities of the gamma rays in singles and coincidence made it possible to construct a decay scheme for ^{108m}In involving all but one of the gamma rays assigned to this decay. This decay scheme is shown in figure 1. The log *ft* values for the β^+/EC transitions to levels in ^{108}Cd were deduced from the measured gamma ray intensities and the decay scheme. The spins and parities, 2^+ and 4^+, of the first two excited states have been established in measurements of Coulomb excitation (Stelson and McGowan 1958, McGowan *et al* 1965, Milner *et al* 1969) and in elastic scattering (Lutz *et al* 1969). Cochavi *et al* (1971 and private communication to F E Bertrand 1972) have assigned spins 6^+ and 5^- to the levels at 2541·6 and 2601·9 keV from measurements of gamma ray angular distributions in the ^{96}Zr(^{16}O,4n)^{108}Cd reaction. The measured values of

Table 1. Energies, relative intensities and transition assignments of gamma rays in the decay of ^{108m}In

Present work		Didorenko *et al* (1970)†		Assignment	
Energy (keV)	Relative intensity	Energy (keV)	Relative intensity	From (keV)	To (keV)
242·8±0·3	38·5±2·0	244·5±0·3	40·0±3·0	2808·2	2565·5
266·5±0·5	3·0±0·4	269·0±0·7	3·4±0·3	2808·2	2541·6
326·0±0·5	13·0±0·8	327·6±0·5	13·0±2·2	2565·5	2239·5
569·0±0·3	5·1±0·6	568·4±0·6	4·7±0·6	3110·6	2541·6
633·1±0·2	100	633·2±0·3	100	633·1	0
648·8±0·4	4·2±0·6	—	—	3190·4	2541·6
730·8±0·4	8·1±1·9	729·9±0·6	7·8±0·5	2239·5	1508·6
875·5±0·4	94·7±7·5	876·0±0·5	85·0±7·0	1508·6	633·1
1033·0±0·3	25·8±1·5	1032·3±0·4	20·0±2·2	2541·6	1508·6
1056·9±0·4	31·3±2·5	1056·3±0·4	25·0±2·2	2565·5	1508·6
1093·3±0·8	4·7±0·6	1092·5±0·8	3·5±0·3	2601·9	1508·6
1197·5±1·0	3·8±0·6	1196·6±0·8	4·2±0·3	—	—
1299·7±0·3	16·4±3·4	1299·2±0·7	10·0±2·1	2808·2	1508·6
1486·1±0·4	4·3±0·6	1486·3±0·8	3·2±0·3	2994·6	1508·6
1606·6±1·0	7·5±1·9	1607·0±0·8	9·0±0·8	2239·5	633·1

† These authors assign a number of other gamma rays to the decay of ^{108m}In. These gamma rays were assigned to the decay of ^{108}In or were not observed in the present work.

Table 2. Observed gamma–gamma coincidences in the decay of ^{108m}In

Gate energy (keV)	Coincident gamma ray energies†‡ (keV)
243	326, 633, 730, 875, 1057, 1606
326	243, 633, 730, 875, 1606
569	633, 875, 1033
633	243, 266, 326, 569, 649, 730, 875, 1033, 1057, 1093, 1199, 1300, 1486, 1606
649	633, 875, 1033
730	243, 326, 633, 649, 875
875	243, 266, 326, 569, 633, 730, 1033, 1057, 1093, 1300, (1199), 1486
1033	266, 569, 633, 875
1057	243. 633, 875
1093	633, 875
1199	633, 875
1300	633, 875
1486	633, 875
1606	243, 326, 633

† The gamma rays listed were observed to be in coincidence in studies of the (^{3}He, 2n) induced activity. Where a gamma ray energy is underlined it was also observed in coincidence in studies of the (p, n) induced activity.

‡ Where there is some doubt about the coincidence assignment the gamma ray energy is enclosed in parentheses.

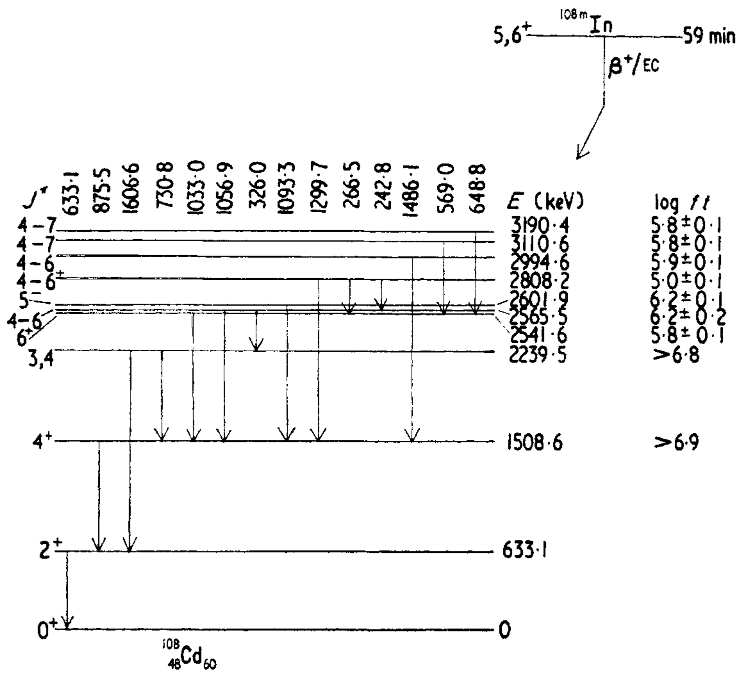

Figure 1. The decay scheme for ^{108m}In.

log *ft* for the transitions to these levels are only consistent with spin 5 or 6 and positive parity for ^{108m}In (Raman and Gove 1973). With this restriction on the spin of the parent state the log *ft* values of the transitions to the other states and their observed gamma decays limit their spins to the range of values shown. Cochavi *et al* (1971) in their study of the ^{96}Zr(^{16}O,4n)^{108}Cd reaction observed an 1199 keV gamma ray. From their coincidence and angular distribution measurements they place it as feeding the 6^+ state from a spin 7 state at 3740 keV, thus correcting the earlier 8^+ assignment for the 3740 keV level made by Hashizume *et al* (1969) on the basis of the $I(I+1)$ rule alone. Unfortunately, the coincidence results obtained for the 1197 keV gamma ray in the present work do not allow it to be placed in the level scheme. If it is the same gamma ray as observed by Cochavi *et al* (1971) then the spin of ^{108m}In is 6 not 5.

It is of some interest that the spin of ^{108m}In differs from that of ^{110m}In which has been measured to be 7^+ (Marino *et al* 1958). Nordheim (1950, 1951) and Brennan and Bernstein (1960) have studied the spins and parities of odd–odd nuclei in the range $20 < A < 120$ in terms of the *j–j* coupling model. They conclude that the low-lying states of an odd–odd nucleus result from a single neutron–proton configuration, namely from combinations of the lowest configuration in the adjacent odd-Z and odd-N nuclei. The model leads to semi-empirical rules for the ground state spins of odd–odd nuclei. For odd nuclei with $Z = 49$ the observed ground state spin is always $9/2^+$ due to the $(g\ 9/2)^{-1}$ proton configuration. For $N > 50$ the neutrons are expected to fill the 2d 5/2 and 1g 7/2 shells. Odd nuclei with $N = 51$, 53 and 55 have spin and parity $5/2^+$ indicating that the 2d 5/2 shell is being filled. Odd Pd and Cd nuclei with $N = 59$ and 61 also have spin and parity $5/2^+$. Thus it appears that the d 5/2 neutron state also lies below the g 7/2 state for these neutron numbers. Nordheim's rules, as modified by Brennan and Bernstein (1960) suggest that the $(\pi g\, 9/2)^{-1}$ $(\nu d\, 5/2)^{-1}$ configuration should lead to states of spin and parity 2^+ and 7^+ lying lowest in energy in ^{110}In, in perfect agreement with experiment (Marino *et al* 1958). The ground states of ^{105}Pd and ^{107}Cd, both with 59 neutrons, have spin and parity $5/2^+$ which leads one to expect that the lowest-lying states in ^{108}In resulting from the $(g\, 9/2)^{-1}$ $(d\, 5/2)^{-3}$ configuration will have spins and parities 2^+ and 7^+ as in ^{110}In. The observed 5^+ or 6^+ spin and parity for ^{108m}In does not fit this picture. Presently available evidence (Bertrand 1972) suggests spin 1/2 or 3/2 for ^{109}Sn(N = 59). If the three d 5/2 neutron holes couple to $3/2^+$ in ^{108}In then rule 2 proposed by Brennan and Bernstein (1960) would give spins and parities 3^+ and 6^+ for the two lowest-lying states in ^{108}In. This is the only explanation consistent with our present knowledge of the spins of these nuclei and the modified Nordheim rules. It implies spins and parities $3/2^+$, 3^+, and 6^+ for ^{109}Sn, ^{108}In and ^{108m}In. Further, the lifetime of the M3 transition which would connect the 3^+ and 6^+ states in ^{108}In is consistent with the observed half-lives of these states.

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