

## DECAY OF $^{109}\text{Pd}$ TO THE LEVELS OF $^{109}\text{Ag}$

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Received 20 January 1983

UDC 539:16

Original scientific paper

The decay of  $^{109}\text{Pd}$  activity has been studied through high resolution gamma spectroscopy. The half-life of the decay of  $^{109}\text{Pd}$  activity has been measured and found to be  $13.85 \pm 0.17$  hour. On the basis of half-life measurements, gamma-rays have been assigned to  $^{109}\text{Ag}$ . A level scheme for  $^{109}\text{Ag}$  has been proposed and the assignment of 706.9, 910.7, 912.2 and 1099.1 keV levels have been confirmed. The spin-parities of the levels of  $^{109}\text{Ag}$  have been discussed. The properties of the levels have been discussed in the light of the theoretical predictions.

### 1. Introduction

Odd mass nuclei in the Pd-Cd region show considerable complexity in the level spectra<sup>1)</sup>. The excitation of the single particle and the coupling of the single particle (or quasi-particle) to the collective vibration of the neighbouring even-even core give rise to a large number of states for the odd nuclei in this region. The  $^{109}\text{Ag}$  nucleus, being a member of this group, also shows a large number of low-lying states. The excited states of  $^{109}\text{Ag}$  nucleus were studied earlier from nuclear reactions<sup>2-5)</sup>, Coulomb excitation<sup>6-8)</sup> and decay<sup>9-12)</sup>. In nuclear reaction, preferential excitation of the states occur depending on the type of reaction. In Coulomb excitation only the negative parity collective states of  $^{109}\text{Ag}$  were excited. However, from the decay studies positive parity states are populated via allowed transitions from the  $5/2^+$  ground state of  $^{109}\text{Pd}$ . In addition to the positive parity states the population of the negative parity states are also probable from the decay

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of  $^{109\text{g}}\text{Pd}$ . Hence, the decay studies provide the scope of observing both the negative and positive states of  $^{109}\text{Ag}$ . Information concerning the level structure, particularly the positive parity levels are of interest to the theoreticians.

The decay of  $^{109\text{g}}\text{Pd}$  to the excited states of  $^{109}\text{Ag}$  have been investigated earlier by Graeffe and Gordon<sup>9)</sup>, Berzins et al.<sup>10)</sup>, Schick and Talbert<sup>11)</sup> and Bashandy<sup>12)</sup>. Although the main features of the decay of  $^{109\text{g}}\text{Pd}$  were established in the previous studies, certain disagreement concerning the existence of a few levels and a considerable amount of discrepancies regarding the intensity of the gamma-rays as well as the placement of the different gamma-rays in the level scheme is noted. Therefore, it was felt that a reinvestigation of the decay of  $^{109\text{g}}\text{Pd}$  would be worthwhile for the establishment of the level scheme of  $^{109}\text{Ag}$ . The result of preliminary investigation on the decay of  $^{109\text{g}}\text{Pd}$  was reported earlier by us<sup>13)</sup>.

## 2. Experimental procedure

The enriched (98.11%)  $^{108}\text{Pd}$  sample (procured from ORNL) was irradiated in the CIRUS reactor of BARC, Bombay in an average flux of  $4.7 \times 10^{13}$  N/cm<sup>2</sup>/s for about 30 hours. The  $^{109\text{g}}\text{Pd}$  activity was produced by (n,  $\gamma$ ) reaction. The gamma-ray singles spectra were taken using a 32.2 cm<sup>3</sup> Ge (Li) detector (2.1 keV resolution at 1332 keV) and a LABEN 4096 channel analyser. To minimise the count rate effect due to the strong 88.0 keV gamma-rays, a 0.32 cm thick cadmium absorber was interposed between the source and the detector in some of the singles measurements. This has enabled us to observe the weak gamma-rays from the decay. The singles gamma-spectra were analysed using the computer code<sup>14)</sup> SAMPO. For the energy measurements both internal and external calibration techniques were adopted. External calibration has been carried out with the  $^{152}\text{Eu}$  and  $^{177\text{m}}\text{Lu}$  sources. The internal calibration was performed with the  $^{110\text{m}}\text{Ag}$  activity produced by the thermal neutron capture of  $^{109}\text{Ag}$ . The efficiency calibration of the detector was done with  $^{177\text{m}}\text{Lu}$  and  $^{152}\text{Eu}$  sources, under identical geometrical conditions. Gamma-gamma coincidence studies have been performed using two Ge (Li) detectors of volumes 2.5 cm<sup>3</sup> and 32.2 cm<sup>3</sup>, respectively, and a coincidence circuit having time resolution  $\sim 150$  ns. The coincidence data were stored using the facility of the two-parameter analysis mode of the LABEN analyser.

## 3. Results

The direct spectrum of the gamma-rays observed in the decay of  $^{109\text{g}}\text{Pd}$  is shown in Fig. 1 a & b. The half-life of  $^{109\text{g}}\text{Pd}$  activity has been measured following the decay through the most intense gamma-ray of energy 88.0 keV. The measured half-life comes out to be  $13.85 \pm 0.17$  hour which is close to the reported value  $13.43$  hour<sup>1)</sup>. The gamma-rays which followed the characteristic half-life of  $^{109\text{g}}\text{Pd}$  decay were assigned to  $^{109}\text{Ag}$ . The gamma-ray intensities have been measured considering internal conversion of the gamma-rays. The energies and intensities of the gamma-rays measured in our work have been compared with other reported results (Table 1). The whole matrix of the two-parameter

TABLE 1.

This work		Berzins et al. <sup>10)</sup>		Bashandy <sup>12)</sup>	
Energy (keV)	Intensity	Energy (keV)	Intensity	Energy (keV)	Intensity
44.7	(49.5/1 + $\alpha_T$ ) <sup>a</sup>	44.7 ± 0.2	4.5	44.8 ± 0.4	4.8 ± 0.5
88.0 ± 0.2	16252 ± 2194	88.1 ± 0.2	11600	88.0 ± 0.4	11700 ± 1150
103.8 ± 0.5	1.59	103.7 ± 0.2	1	103.6 ± 0.4	1.9 ± 0.2
134.2 ± 0.2	8.0 ± 1.3	134.3 ± 0.2	3.7	134.5 ± 0.3	4.0 ± 0.4
145.1 ± 0.2	4.3 ± 1.8	145.4 ± 0.3	2.5	145.5 ± 0.3	3.1 ± 0.3
286.8 ± 0.2	0.84 ± 0.11	—	—	—	—
309.1 ± 0.2	29.8 ± 3.6	309.3 ± 0.5	9	309.1 ± 0.7	11 ± 0.9
311.4 ± 0.2	140.4 ± 15.2	311.3 ± 0.1	85	311.4 ± 0.2	91 ± 8
327.8 ± 0.5	0.52 ± 0.05	—	—	—	—
390.6 ± 0.2	3.6 ± 0.4	390.5 ± 0.3	3.0	390.7 ± 0.5	3.2 ± 0.3
395.4 ± 0.5	0.46 ± 0.13	—	—	—	—
413.1 ± 0.2	32.9 ± 3.7	413.0 ± 0.1	22	413.2 ± 0.2	23 ± 2.0
415.2 ± 0.2	46.0 ± 5.0	415.0 ± 0.1	45	415.1 ± 0.2	45 ± 4.2
424.0 ± 0.2	3.8 ± 0.4	423.9 ± 0.3	3.8	424.0 ± 0.4	3.9 ± 0.3
447.5 ± 0.2	3.6 ± 0.4	447.5 ± 0.2	3.3	447.4 ± 0.3	3.3 ± 0.3
454.3 ± 0.2	1.7 ± 0.2	454.3 ± 0.2	2.5	454.1 ± 0.3	2.3 ± 0.2
497.0 ± 0.2	0.33 ± 0.09	496.9 ± 0.5	0.2	496.7 ± 0.7	0.15 ± 0.03
551.3 ± 0.2	2.6 ± 0.3	551.3 ± 0.2	2.6	551.2 ± 0.3	2.5 ± 0.3
558.1 ± 0.2	9.7 ± 1.0	558.1 ± 0.1	9.8	558.5 ± 0.2	9.6 ± 0.9
602.6 ± 0.2	33.2 ± 3.7	602.5 ± 0.1	34	602.4 ± 0.2	34 ± 3.0
636.3 ± 0.2	41.5 ± 4.5	636.4 ± 0.2	41	636.3 ± 0.3	41 ± 3.8
647.2 ± 0.2	100	647.3 ± 0.1	100	647.3 ± 0.2	100
701.8 ± 0.2	12.6 ± 1.4	702.0 ± 0.2	15	702.0 ± 0.3	14.7 ± 1.2
706.9 ± 0.2	5.6 ± 0.7 <sup>b</sup>	706.9 ± 0.3	6.9	707.1 ± 0.4	7.1 ± 0.7
724.4 ± 0.2	0.27 ± 0.07	724.6 ± 0.3	1.2	724.4 ± 0.5	1.1 ± 0.1
736.5 ± 0.2	6.4 ± 0.7	736.7 ± 0.2	7.8	736.8 ± 0.4	7.7 ± 0.7
777.9 ± 0.2	9.6 ± 1.3	778.3 ± 0.5	4	778.4 ± 0.7	4 ± 0.4
781.2 ± 0.2	50.5 ± 5.6	781.4 ± 0.2	49	781.5 ± 0.3	50 ± 4
822.7 ± 0.2	0.66 ± 0.08	822.9 ± 0.3	0.8	822.7 ± 0.5	0.5 ± 0.1
862.7 ± 0.5	0.68	862.8 ± 0.5	0.6	863.0 ± 0.7	0.3 ± 0.1
966.6 ± 0.5	0.28	966.3 ± 0.5	0.1	966.4 ± 0.7	< 0.1
1011.1 ± 0.5	0.12 ± 0.04	1010.5 ± 0.5	0.1	1010.6 ± 0.9	< 0.1

<sup>a</sup> Shows only the lower limit of the intensity estimated from the gamma-ray transitions populating the 132.7 keV level.  $\alpha_T$  is the total conversion coefficient.

<sup>b</sup> Contribution of the 706.62 keV gamma-ray of <sup>110m</sup>Ag has been subtracted.

Energies and intensities of the gamma-rays in the decay of <sup>109m</sup>Pd.

coincidence data have been analysed. The relevant portions of the coincidence spectra are shown in Fig. 2 a & b. The result of the coincidence study is given in Table 2. A new gamma-ray of energy 327.8 keV (Table 2), which was observed earlier by us<sup>13)</sup> and was later reported by Cottrel<sup>9)</sup> in his Coulomb excitation study is confirmed in this work. Cottrel assigned it as a transition from the 415 keV level to the 88 keV level which is also confirmed from our coincidence study (Fig. 2a).

TABLE 2.

Principal gamma-rays in gate (keV)	Coincidence gamma-rays (keV)
104	286, 309, 311, 390, 413, 448
309, 311	104, 328, 390, 413, 415, 424, 511, 558
413, 415	145, 286, 309, 311, 448, 454, 497

Coincidence relationships among the gamma-rays in the decay of  $^{109}\text{Pd}$ .

On the basis of the measurement of accurate energies and intensities of the gamma-rays and from the coincidence relationships, a level scheme of  $^{109}\text{Ag}$  has been proposed (Fig. 3). It appears from the comparison of the results of our investigation with the other reported results that there is an over all good agreement. However, we would describe only those points where discrepancies were observed. The 45 keV gamma-ray has not been observed by us. To search for this gamma-ray spectrum was taken without absorber. Schick and Talbert<sup>11)</sup> also did not observe the 45 keV gamma-ray. However, we have placed a 44.7 keV transition depopulating the 132.7 keV level which is being populated by four transitions. Most probably due to the efficiency of our Ge (Li) detector at this energy we could not observe this gamma-ray. The intensity of the 103.8 keV gamma-ray could not be measured in the present work due to the interference from impurity line. However, intensity of the gamma-ray has been given from the known branching

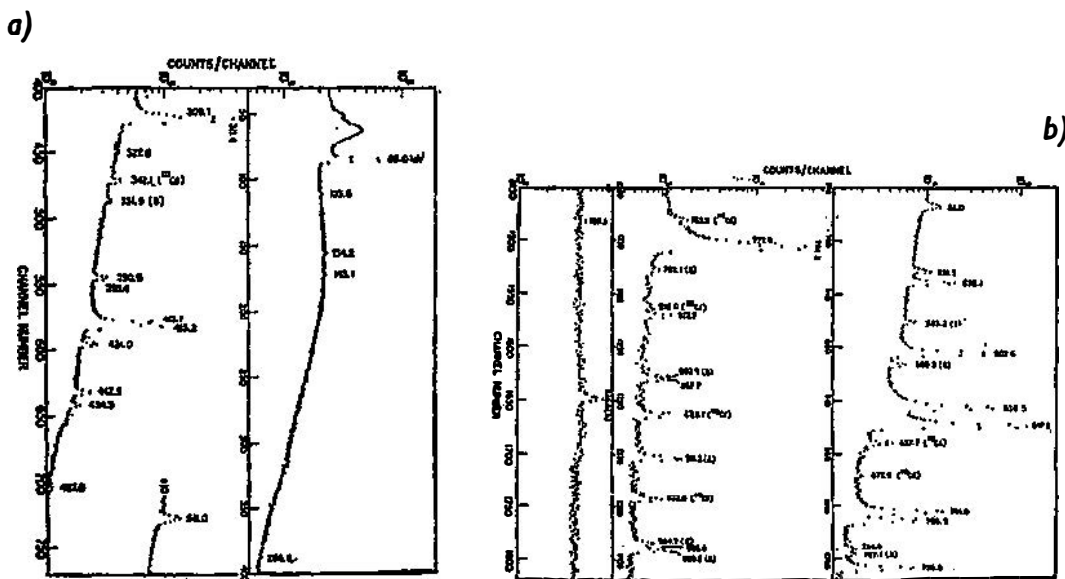


Fig. 1. Gamma-ray spectrum observed in the decay of  $^{109}\text{gPd}$  with the 0.32 cm thick Cd absorber placed between the source and the Ge(Li) detector. The peaks marked (B) correspond to background gamma-ray.

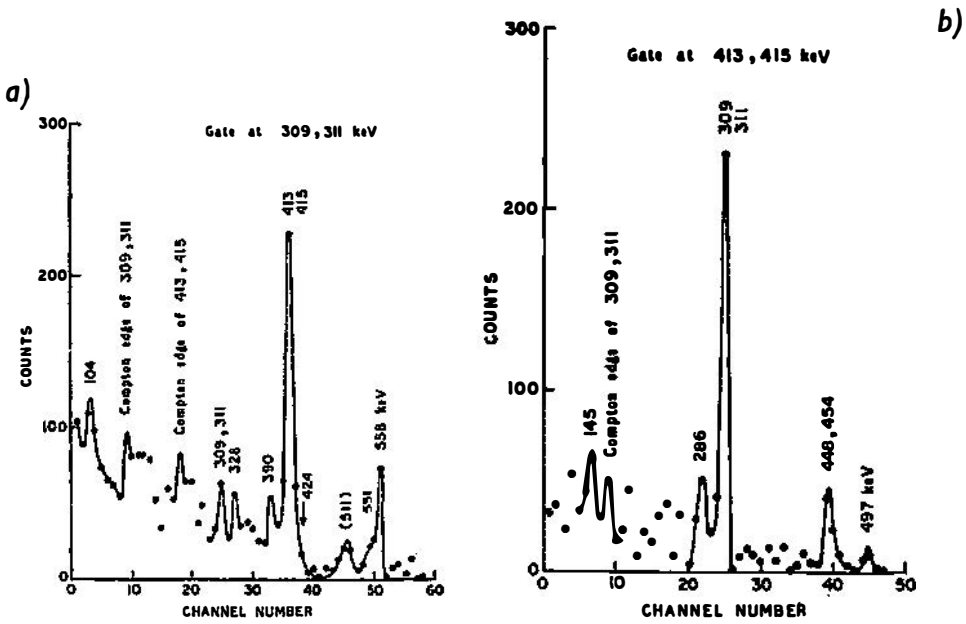


Fig. 2. Gamma-gamma coincidence spectrum in the decay of  $^{109m}\text{Pd}$ .

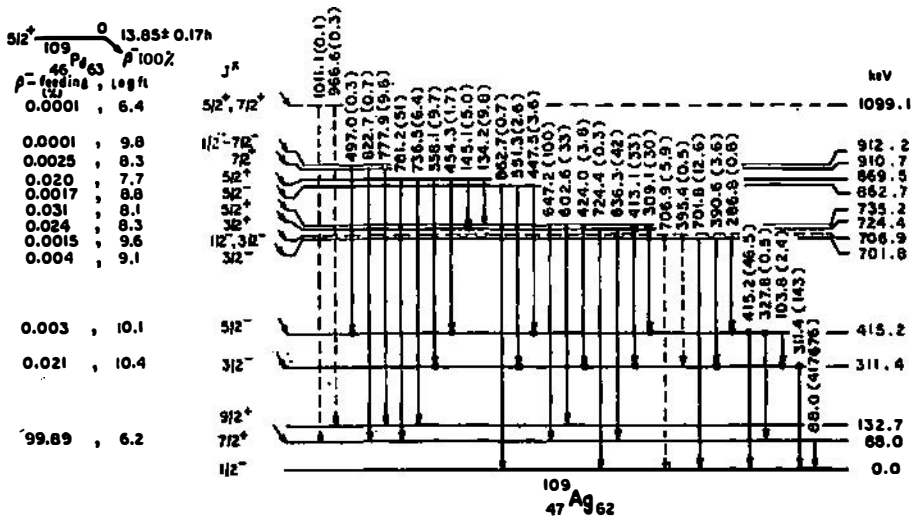


Fig. 3. Level scheme of  $^{109}\text{Ag}$  constructed from the decay of  $^{109m}\text{Pd}$ .

ratio of the transitions from the 415.2 keV level excited in Coulomb excitation<sup>15)</sup>. It also appears that the intensities of the 88.0, 309.1 and 311.4 keV gamma-rays measured by us are considerably more than those obtained by Berzins et al.<sup>10)</sup> and Bashandy<sup>12)</sup>. However, the intensity of 88.0 keV gamma-rays is observed to be very close to that obtained by Schick and Talbert<sup>11)</sup>. The total intensity of the 309.1 and 311.4 keV gamma-ray is very close to those obtained by Schick and Talbert and Graeffe and Gordon<sup>9)</sup> for the composite peak at 311.5 keV.

It appeared from the previous studies<sup>9-12)</sup> that there was controversy regarding assignment of the 707, 840, 911, 912 and 1099 keV levels to <sup>109</sup>Ag. Graeffe and Gordon proposed a level at 840.3 keV on the basis of the coincidence of the 45 keV gamma-ray with the 707 keV gamma-ray. Berzins et al. did not observe this coincidence and so they proposed a level either at 707 keV or at 795 on the basis of 707 keV transition. The 840 keV level has been proposed neither by us nor by other workers. Graeffe and Gordon do not propose the levels at 707, 911, 912 and 1099 keV observed by Berzins et al. and Bashandy. Schick and Talbert proposed the levels at 707 and 911 keV but did not propose the levels at 912 keV and 1099 keV. This is because they were unable to assign the 497 keV transition from the 912 keV level and the 966 and 1011 keV transitions from the 1099 keV level. In the present work the 706.9 keV level has been proposed on the basis of 706.9 keV transition. A level at this energy has also been observed in the (<sup>3</sup>He, d) reaction study by Auble et al.<sup>4)</sup>. We have confirmed the 912 keV level from the coincidence of 497 keV gamma-ray with the 415.2 keV gamma-ray (Fig. 2b). In the present study we have assigned the 910.7 and the 1099.1 keV levels on the basis of the transitions from these levels. The level scheme constructed in the present work is in good agreement with the schemes proposed by Berzins et al. and Bashandy. The levels at 697 keV and 811 keV proposed by El-Bedewi et al.<sup>16)</sup> and included in the recent compilations<sup>1,17)</sup> do not tally with the present observation or earlier studies<sup>9-12)</sup>. None of the transitions from these levels have been observed in the present work except the 609 keV gamma-ray which has been confirmed to be a room background line. The compilations<sup>1,17)</sup> do not cite any other reference in support of these levels and to our knowledge no other work has given any independent evidence for the existence of these levels. It may be noted further that the 402.2 keV and the 790.2 keV transitions from the 1099 keV level have not been observed at all in the present work and in all other previous studies<sup>9-12)</sup>.

#### 4. Spin-assignment

The intensities of the various  $\beta^-$ -groups from the ground state of <sup>109</sup>Pd to the level of <sup>109</sup>Ag have been estimated from the intensity balance of the gamma-rays populating and depopulating each level. The  $\log ft$  values for the various  $\beta^-$ -branches were deduced using the estimated  $\beta^-$ -intensities in a conventional way. On the basis of deduced  $\log ft$  values, the multipolarities of the transitions<sup>12)</sup> and on the information obtained from Coulomb excitation studies<sup>7)</sup>, nuclear reaction studies<sup>4,5)</sup>, the spin-parities of the levels of <sup>109</sup>Ag have been discussed.

The ground state spin-parities of <sup>109</sup>Pd and <sup>109</sup>Ag are known as  $5/2^+$  and  $1/2^-$ , respectively<sup>1)</sup>. The recent (<sup>3</sup>He, d) reaction study of <sup>109</sup>Ag by Auble et al.<sup>4)</sup> also suggests  $1/2^-$  spin-parity for the ground state of <sup>109</sup>Ag.

The low-lying 88.0 keV level has been assigned with the spin of  $7/2^+$ . This spin assignment is consistent with the deduced  $\log ft$  value (6.2) and the  $E3$  multipolarity of the 88.0 keV transition from this level<sup>1,2)</sup>. The 132.7 keV level is assigned with the spin of  $9/2^+$ . This level is populated by a number of transitions from the higher lying levels. The ( $^3\text{He}$ , d) reaction study<sup>4)</sup> suggested a spin-parity of  $9/2^+$  for this level on the basis of  $l$ -transfer. This spin assignment is consistent with the observation of two strong  $E2$  transitions<sup>1,2)</sup> of energies 602.6 and 736.5 keV, respectively, from the higher lying  $5/2^+$  levels to this level.

The proposed levels at 311, 415, 702 and 862 keV have also been observed in Coulomb excitation studies<sup>6,7)</sup>, ( $p$ ,  $p'$ ) scattering experiment<sup>3)</sup> and ( $t$ ,  $p$ ) reaction study<sup>5)</sup>. The 311, 415, 702 and 862 keV levels are assigned with the spin-parities of  $3/2^-$ ,  $5/2^-$ ,  $3/2^-$  and  $5/2^-$ , respectively. The deduced  $\log ft$  values for these levels are consistent with these spin assignments.

The spin-parity of the tentative level at 706.9 keV is suggested by us as either  $1/2^-$  or  $3/2^-$ . The  $M1$  or  $E2$  multipolarity of the 706.9 keV transition<sup>1,2)</sup> from this level to the ground state and the 395.4 keV transition to the 311.4 keV ( $3/2^-$ ) level suggest this spin assignment. This is corroborated by the  $\log ft$  value (9.8) for this level deduced in the present work.

The 724.4 keV and 735.2 keV levels are assigned with the spins of  $3/2^+$  and  $5/2^+$ , respectively. The  $E1$  multipolarity of 413.1 keV transition from the 724.4 keV level to the 311.4 keV ( $3/2^-$ ) level and other transitions from this level and the angular correlation study<sup>1,8)</sup> suggests the most appropriate spin of  $3/2^+$  for this level. Similarly the  $E1$  multipolarity<sup>1,2)</sup> of the 424.0 keV transition from the 735.2 keV level to 311.4 ( $3/2^-$ ) level and other transitions from this level to the low-lying states suggest the spin of  $5/2^+$  for this level. The deduced  $\log ft$  value for the 724.4 keV and 735.2 keV levels are consistent with these spin assignments.

The 869.5 and 910.7 keV levels are assigned with the spin-parities of  $5/2^+$  and  $7/2^+$ , respectively. The  $E1$  multipolarity of the 558.1 keV transition from the 869.5 keV level to the 311.4 keV ( $3/2^-$ ) level and the other transitions from this level to the low-lying states suggest  $5/2^+$  spin-parity for this level. This spin-parity is consistent with the deduced  $\log ft$  value and the observed  $l$ -transfer in ( $^3\text{He}$ , d) reaction study. The 910.7 keV level deexcites through two transitions to the 88.0 keV ( $7/2^+$ ) and 132.7 ( $9/2^+$ ) levels. The deduced  $\log ft$  value (8.3) suggests  $5/2^+$ ,  $7/2^+$  spin-parity for this level. However, from the ( $^3\text{He}$ , d) reaction study the assignment of  $7/2^+$  spin seems to be most likely for this state.

The 912.2 keV level has been observed from the Coulomb excitation studies<sup>6,7)</sup>, ( $p$ ,  $p'$ ) scattering experiment<sup>3)</sup> and ( $t$ ,  $p$ ) reaction study<sup>5)</sup>. This level is seen from the decay and is deexcited by a 497.0 keV transition. As this level has been excited in Coulomb excitation, it seems to be a negative parity level. From the  $\log ft$  consideration any spin between  $1/2^-$  —  $7/2^-$  is possible for this level. The 1099.1 keV level is proposed in the present work on the basis of two transitions of energies 966.6 and 1011.1 keV, respectively, leading to the 132.7 keV ( $9/2^+$ ) and 88.0 keV ( $7/2^+$ ) levels. The deduced  $\log ft$  value (6.4) and the observed modes of deexcitation suggest spin of  $5/2^+$  or  $7/2^+$  for this level. This requires further independent confirmation.

## 5. Discussion

In the present study, apart from the confirmation of the existence of several weak transitions and a number of levels, tentative spins of the levels have been assigned from the deduced  $\log ft$  values. A discussion on the spin-parities, of the levels with the arguments based on known information from other studies has made it possible to assign uniquely the spin-parities of a number of levels. However, the spin of 706.9, 912.2 and 1099.1 keV levels could not be assigned uniquely. The weak  $\beta^-$ -feedings to these levels are the main constraints for the spin determination from gamma-gamma angular correlation studies. Hence, it will be interesting to study these states from gamma-ray angular distributions following the  $^{108}\text{Pd}(d, n\gamma)$  or  $^{108}\text{Pd}(^3\text{He}, d\gamma)$  reactions.

The negative parity states in  $^{109}\text{Ag}$  can be described in terms of particle phonon weak coupling model of de-Shalit<sup>19)</sup>. The  $^{109}\text{Ag}$  nucleus can be bracketted with  $^{108}\text{Pd}$  and  $^{110}\text{Cd}$  which have shown collective vibrational spectra for the low-lying states<sup>20,21)</sup>. Hence, the description of the negative parity states in terms of the core particle coupling seems to be a promising approach. It has been observed in Coulomb excitation studies<sup>15)</sup> that the 311 keV and 415 keV states are predominantly collective in nature and arise due to the coupling of a  $2p_{1/2}$  proton to the first  $2^+$  state of the neighbouring even-even core. Similarly the 702 and 863 keV states can be described as the coupling of  $p_{1/2}$  proton to the  $2^+$  two phonon state of the neighbouring even-even core. The other states which may arise from the coupling of  $p_{1/2}$  proton to the  $0^+$ ,  $4^+$  two phonon states of the core nucleus, have not been identified from Coulomb excitation studies excepting the state at 912 keV which may be a member of that multiplet.

The most important findings of the decay studies is the observation of several low-lying positive parity levels. In this region immediately below  $Z = 50$  closed shell, the low-lying single particle levels are  $2p_{1/2}$  and  $1g_{9/2}$ . The level at 133 keV may be described as due to the single particle level  $g_{9/2}$ . If one considers the single proton in  $g_{9/2}$  orbital, in a similar weak coupling picture one would expect a multiplet of positive parity levels with spins ranging from  $5/2$  to  $13/2$  with its centre of gravity around 370 keV. The absence of any positive parity level in that energy range and a very low-lying  $7/2^+$  (88 keV) state suggest much more complicated feature of the positive parity states in  $^{109}\text{Ag}$  and other odd nuclei of Ag.

Although several approaches were made in the framework of core particle coupling model<sup>22-24)</sup> to explain the low-lying negative parity states of  $^{109}\text{Ag}$  a little effort was given earlier to explain the positive parity states. The calculation based on Alaga model involving the three proton hole cluster configuration coupled to the quadrupole vibration of the Sn nucleus by Paar<sup>25)</sup>, explains two major features of the level structures, namely, the low-lying  $7/2^+$  state and the large gap between the  $9/2^+$  level and the next positive parity  $5/2^+$  level. The  $7/2^+$  state can not be explained as a single proton hole shell model state because of its low-energy as it was pointed out by Talmi and Unna<sup>26)</sup>. The low spectroscopic strength observed for this state in  $(^3\text{He}, d)$  reaction also supports the statement of Talmi and Unna. From the three proton hole coupling model Paar has suggested the existence of the states with spins  $11/2^+$ ,  $15/2^+$ ,  $17/2^+$  around 1.4 MeV. It is not possible to observe these states from the decay studies or from the single particle transfer reaction studies. Such states have been observed in  $^{105}\text{Ag}$  from

$^{103}\text{Rh}$  ( $\alpha, 2n\gamma$ ) reactions<sup>27,28</sup>) and in  $^{107}\text{Ag}$  from  $^{104}\text{Ru}$  ( $^6\text{Li}, 3n\gamma$ ),  $^{104}\text{Ru}$  ( $^7\text{Li}, 4n\gamma$ ) reactions<sup>29</sup>). So heavy ion reaction experiments are sought for observing these high spin positive parity states in  $^{109}\text{Ag}$ .

#### Acknowledgments

The authors express gratitude to Prof. A. P. Patro and Prof. B. Basu for their kind interest in this work. Thanks are due to Mme Diane C. Voisine of Van de Graaff Laboratory, Université Laval for her help in the preparation of this manuscript.

#### References

- 1) C. M. Lederer and V. S. Shirley, *Table of Isotopes*, 17th Edition (New York: Wiley), 1978;
- 2) W. M. Steward, N. Baron and R. F. Leonard, *Phys. Rev.* **171** (1968) 1316;
- 3) J. L. C. Ford Jr., R. L. Robinson, P. H. Stelson, T. Tamura and C. Wong, *Nucl. Phys. A* **142** (1970) 525;
- 4) R. L. Auble, F. E. Bertrand, Y. A. Ellis and D. J. Horen, *Phys. Rev. C* **8** (1973) 2308;
- 5) R. A. Naumann, in *Proceed. of 3rd International Conf. on Nuclei Far from Stability* CERN 76-13 (1976) 42;
- 6) J. L. Black and W. Gruhle, *Nucl. Phys. A* **93** (1967) 1;
- 7) R. L. Robinson, F. K. McGowan, P. H. Stelson and W. T. Milner, *Nucl. Phys. A* **150** (1969) 225;
- 8) C. W. Cottrel, *Nucl. Phys. A* **204** (1973) 161;
- 9) G. Graeffe and G. E. Gordon, *Nucl. Phys. A* **107** (1967) 67;
- 10) G. Berzins, M. E. Bunker and J. W. Starner, *Nucl. Phys. A* **114** (1968) 512;
- 11) W. C. Schick Jr. and W. L. Talbert Jr., *Nucl. Phys. A* **128** (1969) 353;
- 12) E. Bashandy, *Z. Phys.* **236** (1973) 130;
- 13) M. B. Chatterjee and B. B. Baliga, *Nucl. Phys. and Solid State Phys. (India)* **15 B** (1972) 363;
- 14) J. T. Routti, UCRL-19452 Lawrence Radiation Laboratory, California (1969);
- 15) M. B. Chatterjee, Ph. D. Thesis, Calcutta University (1978);
- 16) F. El-Bedewi, Z. Miligy and H. Hanafi, *Acta Phys. Acad. Sci. Hung.* **38** (1975) 153;
- 17) F. E. Bertrand, *Nuclear Data Sheets* **23** (1978) 229;
- 18) H. E. Bosch, V. M. Shilbergleit, M. Davidson and J. Davidson, *Can. J. Phys.* **55** (1977) 175;
- 19) A. de-Shalit, *Phys. Rev.* **122** (1961) 1530;
- 20) R. L. Robinson, F. K. McGowan, P. H. Stelson and R. O. Sayer, *Nucl. Phys. A* **124** (1970) 553;
- 21) W. T. Milner, F. K. McGowan, P. H. Stelson, R. L. Robinson and R. O. Sayer, *Nucl. Phys. A* **129** (1969) 687;
- 22) S. C. Gujrathi and B. P. Pathak, *Lett. Nuovo Cim.* **1** (1971) 887;
- 23) I. M. Naqib, D. J. Thomas and W. Wakefield, *J. Phys. A* **6** (1973) 1580;
- 24) O. Civitarese and F. Krmpotic, *Nucl. Phys. A* **229** (1974) 133;
- 25) V. Paar, *Nucl. Phys. A* **211** (1973) 39;
- 26) I. Talmi and I. Unna, *Nucl. Phys.* **19** (1960) 225;
- 27) D. Hippe, H.-W. Schuh, B. Heits, A. Rademacher, K.-O. Zell, P. v. Brentano, J. Eberth and E. Eube, *Z. Phys. A* **284** (1978) 329;
- 28) A. W. B. Kalshoven, W. H. A. Hesselink, T. J. Ketel, J. Ludziejewski, L. K. Peker, J. J. Van Ruyven and H. Verheul, *Nucl. Phys. A* **315** (1979) 334;
- 29) H.-W. Schuh, D. Hippe, L. Cleemann, J. Eberth, R. Vorwerk, K.-O. Zell and P. v. Brentano, *Z. Phys. A* **293** (1979) 301.

NUKLEARNI RASPAD JEZGRE  $^{109}\text{Pd}$  I STANJA JEZGRE  $^{109}\text{Ag}$

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UDK 539.16

Originalni znanstveni rad

Istraživan je raspad atomske jezgre  $^{109}\text{Pd}$  pomoću gama spektroskopije s visokom moći razlučivanja. Izmjereno je vrijeme poluraspada  $^{109}\text{Pd}$ :  $13,85 \pm 0,17$  h. Na osnovi mjerenja vremena poluraspada pridružene su gama linije i izveden energetski spektar jezgre  $^{109}\text{Ag}$ . Potvrđena je identifikacija stanja na 706,9, 910,7, 912,2 i 1099,1 keV. Analizirani su spinovi i pariteti stanja na osnovi eksperimentalnih rezultata i prikazana je usporedba s teorijskim rezultatima nuklearnih modela