The reasons for this are that (1) Both emerging alpha particles are observed rather than just one product; (2) All the energy of the incident alpha particle is carried off by the two reaction alpha particles; (3) The alpha come off preferentially at the kinematical separation angle of 87.5°; and (4) Each alpha particle has the correct energy, namely, the kinematical energy corresponding to two-body collisions of equal mass particles.

It is, of course, possible that the incident alpha could strike a moving nucleon in the nucleus and transfer the proper amount of energy and, that, when the proton came out, it picked up a triton (or three nucleons) and the necessary momentum to appear with 180 MeV and leave the residual nucleus nearly at rest. In order for this to happen, however, the proton would have to have a momentum very different from the expected momentum distribution.

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The Energy Levels of Pd^{106} Populated in the Decays of Ag^{106} and Rh^{106}†

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The conversion electrons of 5 high-energy transitions in the decay of Ag^{106} have been observed in a permanent magnet spectrograph. The following transitions (in MeV) were observed: the relative intensities of the *K*-conversion electron lines are given in parentheses: 1.0461(40), 1.1298(19), 1.2010(15), 1.2237(5), and 1.5285(12). These transitions can be fitted into a Pd^{106} level scheme, with slight modifications, proposed by Smith. This scheme was based on gamma-ray and low-energy conversion electron studies. The modified Pd^{106} level diagram is compared with the predictions of several nuclear models.

INTRODUCTION

THE study of the energy levels of $_{46}Pd^{106}$ populated by the electron capture decay of $_{47}Ag^{106}$ and by the negatron emission of $_{45}Rh^{106}$ has been reported in three recent publications. Robinson, McGowan, and Smith[1] made measurements of the gamma rays (singles spectra, coincidences, and angular correlations) emitted by Ag^{106} and Rh^{106}. Schemes of the energy levels of Pd^{106} populated by these two decays were presented. Smith[2] studied the low-energy (less than 0.935 MeV) conversion electrons of these two isotopes. Only two transitions were observed in the Rh^{106} decay and that level sequence was not changed. The Pd^{106} level scheme deduced from the Ag^{106} decay data was revised slightly from the one given in reference 1. The revised level diagram is shown in Fig. 1. Ambiye and others[3] reported on the results of gamma-ray coincidence, beta-spectrum, and beta–gamma ray coincidence measurements on Rh^{106}. This work corroborated the level scheme of Robinson *et al.*[1]; spin and parity assignments for the two highest lying levels were suggested. The existence of the (4+) level at 1.23 MeV shown in Fig. 1 was verified by the excitation with 45-MeV oxygen ions of this state by Eccleshall *et al.*[4]

The observation of the conversion electrons of the high-energy transitions in the decay of Ag^{106} is presently reported. These results generally confirm the level scheme presented in reference 2. It was necessary to change only the higher lying levels of Pd^{106}. The levels at 2.7336 and 2.3636 or 1.9469 MeV were removed and levels at 2.7384 and 2.0771 MeV were added.

EXPERIMENTAL PROCEDURE AND RESULTS

The Ag^{106} production and separation has been described previously.[5] The conversion electron lines were observed in a permanent magnet spectrograph with a field of 520 G. Intensity measurements were made with a photodensitometer and chart recorder. The relative energy measurement errors are estimated to be $\sim$0.05%; the absolute energy errors are estimated to be $\sim$0.1%. The intensity errors of the strong lines are probably $\sim$15% and for the weak lines $\sim$25%.

The present experimental results are given in Table I, together with the results of Alburger and Toppel.[6]

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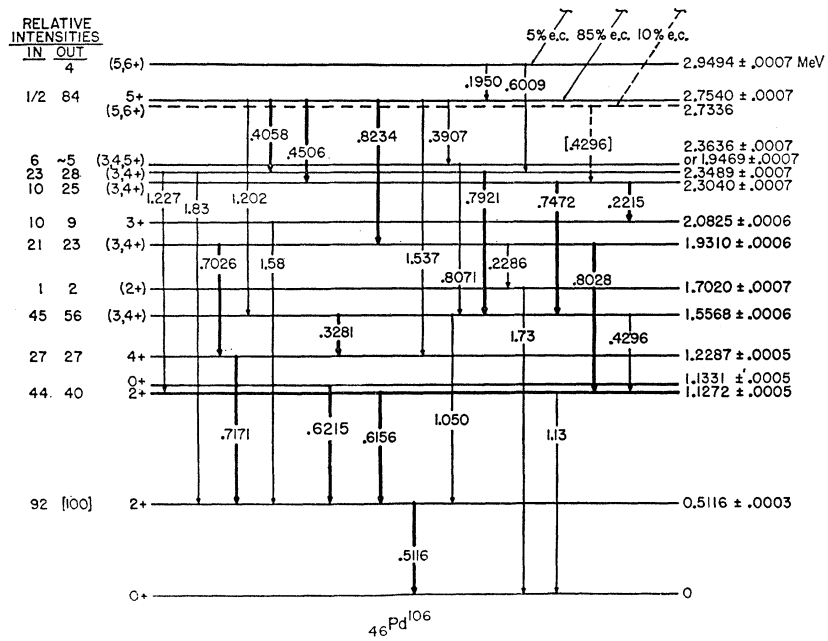

FIG. 1. Pd¹⁰⁶ level scheme of reference 2.

Also shown in this table are the results of the gamma-ray study of Robinson *et al.*[1] and the low-energy conversion data of Smith.[2] (There were typographical errors in the exponents of the conversion coefficients of the higher energy transitions listed in Table III of reference 2, these have been corrected.)

DISCUSSION

It was noted in reference 2 that there was no gamma ray observed which could be closely associated with the rather strong K line of a 0.8234-MeV transition. Therefore, the 0.847-MeV gamma ray was interpreted as the 0.8234-MeV gamma. In this work a K-conversion electron line of an 0.8484-MeV transition was seen, and this is assumed to be the same as the 0.847 gamma.

If the 0.8234-MeV transition is an $M1$-$E2$, the gamma-ray intensity would be about 20 units. It definitely appears that no gamma ray with this energy and intensity is present. Therefore, it is assumed that this is a higher multipole transition, and it is not included in the present level scheme.

An experimental conversion coefficient of $\sim 4\times 10^{-4}$

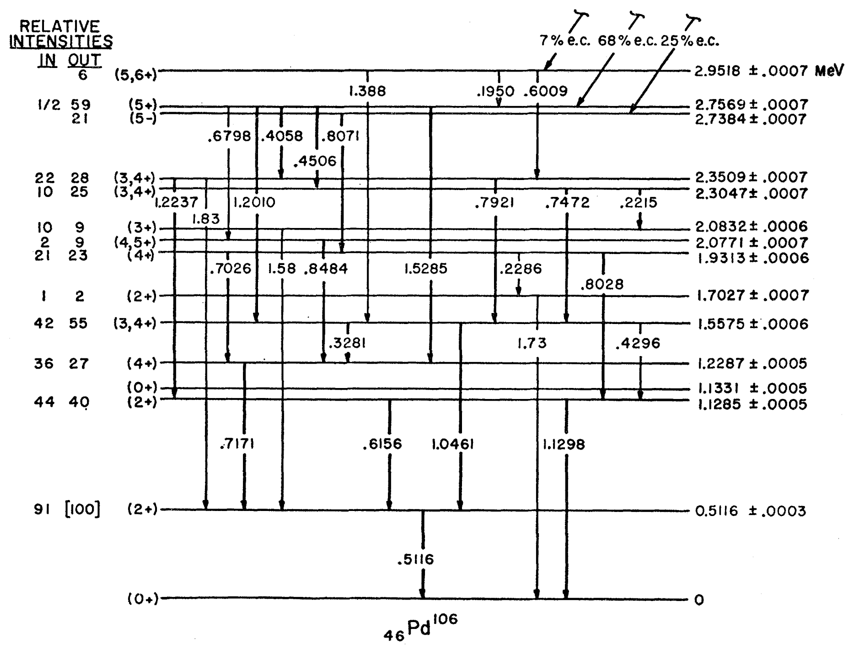

FIG. 2. Pd¹⁰⁶ level scheme based on all conversion electron data and gamma-ray data of Robinson *et al.* (reference 1). The heavy arrows represent transitions for which both the conversion electrons and the gamma rays were observed; the lighter arrows indicate that only the conversion electrons or the gamma rays were observed. The level populations shown were determined from the decay of Ag¹⁰⁶—the (0+) level at 1.1331 MeV was populated only in the decay of Rh¹⁰⁶.

TABLE I. Ag^{106} conversion electron and gamma-ray data.

Transition energy (MeV)	Observed intensities K	L	M	K/L	Alburger and Toppel[a] intensities K	K/L	Experimental gamma-ray intensities (RMS)	Experimental conversion coefficients	Multi-polarity	Theoretical conversion coefficient[e]	Calculated gamma-ray intensities
0.1101	12										
0.1668	ω[b]										
0.1950	35								[*M*1-*E*2]	6×10^{-2}	½
0.2215	430	51	ω	8½	180	3.2	10 ±3	3.8×10^{-2}	*M*1	4×10^{-2}	
0.2286	53	ω							[*M*1-*E*2]	5×10^{-2}	1
0.2820	ω										
0.3281	50						1.1±0.6	4×10^{-2}	*M*1-*E*2	1.9×10^{-2}	
0.3744	ω										
0.3907	65	ω							[*M*1-*E*2]	9.5×10^{-3}	6
0.3965	ω										
0.4058	180	ω			135				[*M*1-*E*2]	8.5×10^{-3}	19
0.4185	ω										
0.4296	160	[20][c]	ω						[*M*1-*E*2]	7.0×10^{-3}	20
0.4506	[90][c,d]	ω	ω				10 ±2	8×10^{-3}	*M*1-*E*2	6.5×10^{-3}	
0.4573	ω										
0.4743	ω										
0.5116	[567]	66	ω	8½	567	7.7	[100]		[*E*2]	4.95×10^{-3}	
0.5857	ω										
0.6009	~10								[*M*1-*E*2]	3.0×10^{-3}	3
0.6156	95	ω			95		27 ±1	3.1×10^{-3}	*M*1-*E*2	3.0×10^{-3}	
0.6798	~ 5								[*M*1-*E*2]	2.4×10^{-3}	2
0.7026	~10						9 ±2	9×10^{-4}	*M*1-*E*2	2.0×10^{-3}	
0.7171	80				78		27 ±3	3.0×10^{-3}	*M*1-*E*2	2.0×10^{-3}	
0.7376	~ 5								[*M*1-*E*2]	1.9×10^{-3}	2
0.7472	24						15 ±3	1.4×10^{-3}	*M*1-*E*2	1.7×10^{-3}	
0.7921	18						14 ±3	1.1×10^{-3}	*M*1-*E*2	1.6×10^{-3}	
0.8028	20				45		13 ±3	1.3×10^{-3}	*M*1-*E*2	1.6×10^{-3}	
0.8071	~10						21 ±3	4×10^{-4}	*E*1	6.0×10^{-4}	
0.8234	33										
0.8484	~12						9 ±4	1.2×10^{-3}	*M*1-*E*2	1.5×10^{-3}	
1.045	40				37		34 ±2	9×10^{-4}	*M*1-*E*2	9×10^{-4}	
1.131	19				13		13 ±1	8×10^{-4}	*M*1-*E*2	7×10^{-4}	
1.205	15				12		11 ±1	10×10^{-4}	*M*1-*E*2	6×10^{-4}	
1.225	5				7		11 ±1	5×10^{-4}	*M*1-*E*2	6×10^{-4}	
1.388	···				1.8		1.8±0.6	8×10^{-4}	*E*3	8×10^{-4}	
1.53	12				10		17 ±2	4×10^{-4}	*M*1-*E*2	4×10^{-4}	

[a] See reference 6.
[b] ω = weak.
[c] [ ] = assumed or adjusted value.
[d] 20 intensity units subtracted for contribution of 429.6-*L* electrons.
[e] Nearly independent of *M*1-*E*2 mixing ratio since *M*1 and *E*2 conversion coefficients are approximately equal.

was obtained for the 0.8071-MeV transition. This indicates that it is an *E*1 transition; theoretical coefficient is 6×10^{-4}. All of the other transitions for which experimental conversion coefficients could be obtained are in agreement with *M*1 and/or *E*2 multipolarity assignments. Consequently, it is assumed that all of the levels except the one depopulated by the 0.8071 transition have the same parity, (+).

A Pd^{106} level scheme based on all of the conversion electron and gamma ray results is shown in Fig. 2. The level energies in Figs. 1 and 2 differ slightly due to the inclusion in the latter of the energies of the higher energy transitions which were measured in the present work.

There are three levels, 1.5575, 2.0771, and 2.3074 MeV, for which the intensity out of the level is considerably larger than the intensity in. Probably these levels are fed by some of the weaker transitions which are not included in the scheme.

The log*ft* values of the electron capture decay branches of Ag^{106} to the 2.9518-, 2.7569-, and 2.7384-MeV levels can be calculated using the half-life of Ag^{106} (8.46 days) and the decay energy (3.00 MeV) obtained from the $Pd^{106}(p,n)$ threshold data of Johnson and Galonsky.[7] They are 4.7, 5.1, and 5.6, respectively. The first two are interpreted as allowed transitions and the latter as once-forbidden. All of these log*ft* values are relatively low which may indicate that the decay energy obtained from the experimental $Pd^{106}(p,n)$ data is slightly low.

The spins and parities of the levels were discussed in detail in reference 2 and only those levels which have been amended will be discussed here.

1.2287-MeV Level

As noted earlier this level was Coulomb excited with heavy ions by Eccleshall *et al.*[4] The relatively large magnitude of the excitation cross section verified the collective nature of this level.

[7] C. H. Johnson and A. Galonsky, Bull. Am. Phys. Soc. **5**, 443 (1960).

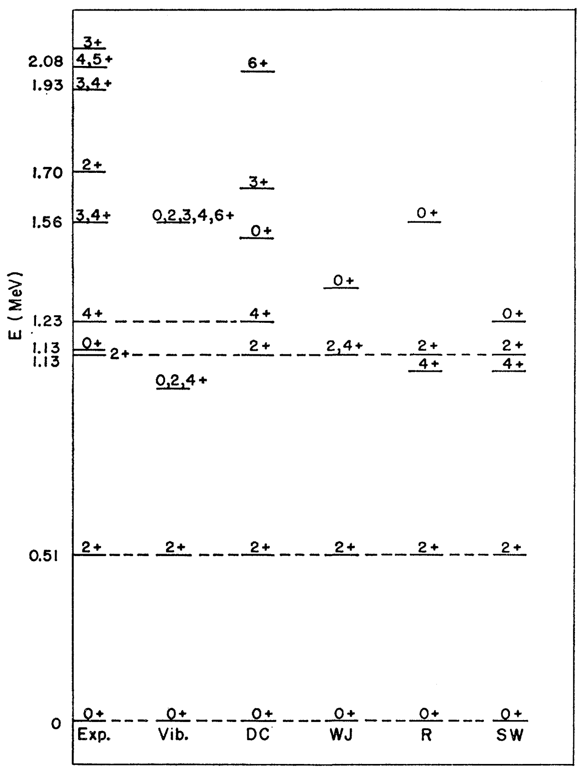

FIG. 3. Comparison of the Pd^{106} level diagram with predictions of nuclear models: Exp—experimental; Vib—pure vibrational model; DC—Davydov and Chaban, $\gamma=22\frac{1}{2}°$, $\mu=0.5$; WJ—Wilets and Jean, Fig. 2, $X_0=1.8$; R—Raz, Fig. 3, $X=1.2$; SW—Scharff-Goldhaber and Weneser, Fig. 3, $K=1.7$. These models are discussed in references 8–11, respectively.

2.7384- and 1.9313-MeV Levels

The measured spin of Ag^{106} is 6. It is inferred from the logft value that the electron capture branch to the 2.7384-MeV level is once forbidden; the conversion coefficient of the 0.8071-MeV transition de-exciting this level indicates an $E1$ character. This requires that the spin and parity of the level be (5, 6, 7−). [It is inferred from the other experimental conversion coefficients that all the other levels have (+) parity.] The 1.9310-MeV level which is populated by the 0.8071-MeV transition is de-excited by $M1$ and/or $E2$ transitions to known (4+) and (2+) levels. This requires the 1.9310-MeV level to be (2, 3, 4+). The only assignments which are consistent with all of these data are (5−) and (4+) for the 2.7384- and 1.9313-MeV levels, respectively.

2.0771-MeV Level

Since this level is populated from a (5+) state and depopulates to a (4+) state, it is suggested to be (4, 5+).

In a large number of nuclei with $24 \leq N \leq 88$ there have been observed one or more of the triplet levels (0+), (2+), and (4+); which occur at ~2.2 times the energy of the first (2+) state. The collective nature of the (2+) and (4+) members of the triplets has been demonstrated in many cases by the relatively large production cross sections for Coulomb excitation. The predominantly quadrupole character of the transitions between the second and first (2+) levels is attributed to the collective behavior of these nuclei.

A number of nuclear models based on collective modes of excitation have been developed to assist in the interpretations and identification of nuclear levels in this neutron number region. In Fig. 3 a comparison of the experimentally observed lower lying (up to ~2-MeV) levels of Pd^{106} is made with five different models which do predict three closely spaced (0+), (2+), and (4+) levels.[8–11] The dashed lines connecting experimental and theoretical levels in this figure indicate the use of the experimental level energies to adjust the parameters in the theories.

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