Lifetime measurement of excited states in ^{105}Ag

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(Received 26 August 1985)

The levels up to about 2.1 MeV in ^{105}Ag were excited via ^{105}Pd(p,nγ) reaction. For the first time, lifetimes of energy levels at 1023, 1042, 1097, 1166, 1243, 1295, 1328, 1386, 1442, 1543, 1558, 1587, 1719, 1923, and 2081 keV have been measured using the Doppler shift attenuation technique.

The excited states of ^{105}Ag have been studied by many workers[1–4] using different reactions and the decay of 55 min ^{105}Cd activity.[5,6] The experimental information summarized by Ellis[7] reveals that lifetimes of almost all of the states in ^{105}Ag are unknown. Further, in this nucleus many states decay through $M1$-$E2$ multipoles.[7] Therefore, many levels in this nucleus must have lifetimes in the picosecond range, which can best be measured by the Doppler shift attenuation (DSA) technique. The present work was, therefore, undertaken to measure the lifetimes of higher excited states. The ^{105}Pd(p,nγ) reaction is mainly a compound nucleus reaction. If the incident proton carries enough angular momentum, essentially all the low lying states will be populated irrespective of their structure. Further, ^{105}Ag constitutes one of the few suitable cases, where target spin being ($\frac{5}{2}$), it is possible to populate an $\frac{11}{2}$ state in the region around 2 MeV or below strongly enough to be observed in a Ge(Li) detector.

The excited states of ^{105}Ag were observed following the reaction ^{105}Pd(p,nγ)^{105}Ag using 4.2, 5.2, and 5.5 MeV pro-

TABLE I. Excitation energy of the levels, attenuation factors, and lifetimes for transitions deexciting the levels of ^{105}Ag. The error in experimental $F(\tau)$ is due to the uncertainty in the location of the peak.

E_{level} (keV)	E_γ (keV)	Experimental $F(\tau)$	Average $\overline{F(\tau)}$	Lifetime τ (fs)
1023.4(1)	590.32(5)	0.30(5)	0.28(4)	78^{+20}_{-16}
	676.59(8)	0.26(5)		
1042.5(1)	695.84(9)	0.23(5)	0.24(4)	97^{+30}_{-20}
	609.29(7)	0.25(5)		
1097.2(1)	1071.57(7)	0.41(6)	0.41(5)	42^{+10}_{-7}
	1043.95(6)	0.40(7)		
1166.4(1)	733.07(8)	0.37(6)	0.37(6)	50^{+16}_{-10}
1243.5(1)	896.51(9)	0.14(4)	0.14(4)	195^{+85}_{-55}
1294.8(1)	1294.85(6)	0.50(7)	0.48(5)	35^{+8}_{-5}
	948.07(6)	0.46(7)		
1328.0(1)	1302.42(5)	0.19(4)	0.21(3)	120^{+45}_{-25}
	1274.75(6)	0.23(5)		
1386.2(1)	1360.73(7)	0.29(4)	0.29(4)	75^{+20}_{-15}
1441.8(1)	1388.42(8)	0.44(7)	0.44(7)	38^{+12}_{-10}
1543.3(1)	1196.34(9)	0.39(6)	0.39(6)	47^{+15}_{-10}
1557.8(1)	1557.82(7)	0.59(10)	0.59(10)	22^{+10}_{-8}
1586.9(1)	1586.87(8)	0.36(7)	0.38(5)	47^{+15}_{-10}
	1239.91(8)	0.40(7)		
1718.9(1)	1693.30(7)	0.68(12)	0.67(8)	16^{+7}_{-5}
	1665.60(6)	0.65(10)		
1922.9(1)	1897.58(8)	0.50(6)	0.53(4)	27^{+6}_{-5}
	1869.70(9)	0.57(7)		
	1489.77(7)	0.53(6)		
2081.1(1)	2056.11(8)	0.58(9)	0.60(6)	21^{+6}_{-5}
	2028.41(8)	0.61(9)		

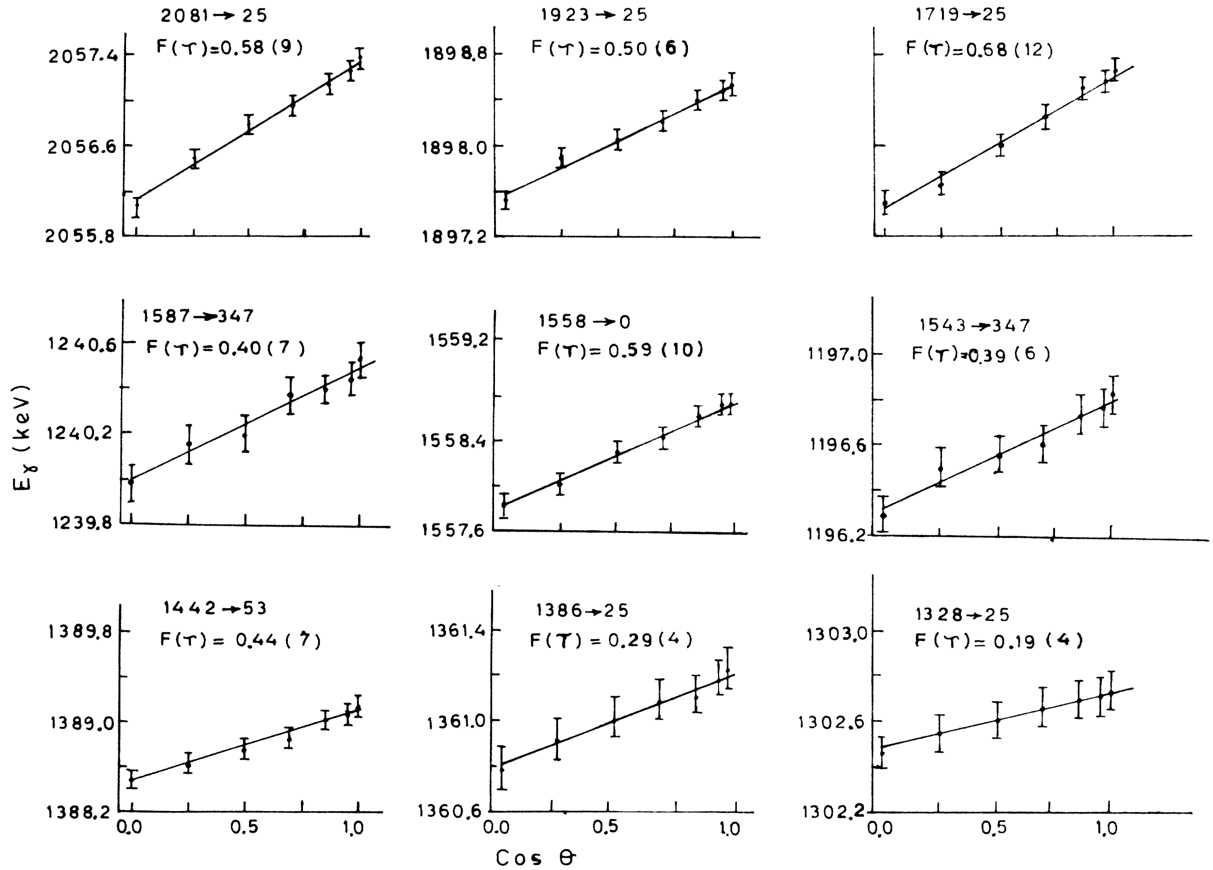

FIG. 1. Plots of E_θ vs $\cos\theta$ for several γ transitions in ^{105}Ag. The straight lines represent the least-squares fits to the experimental data.

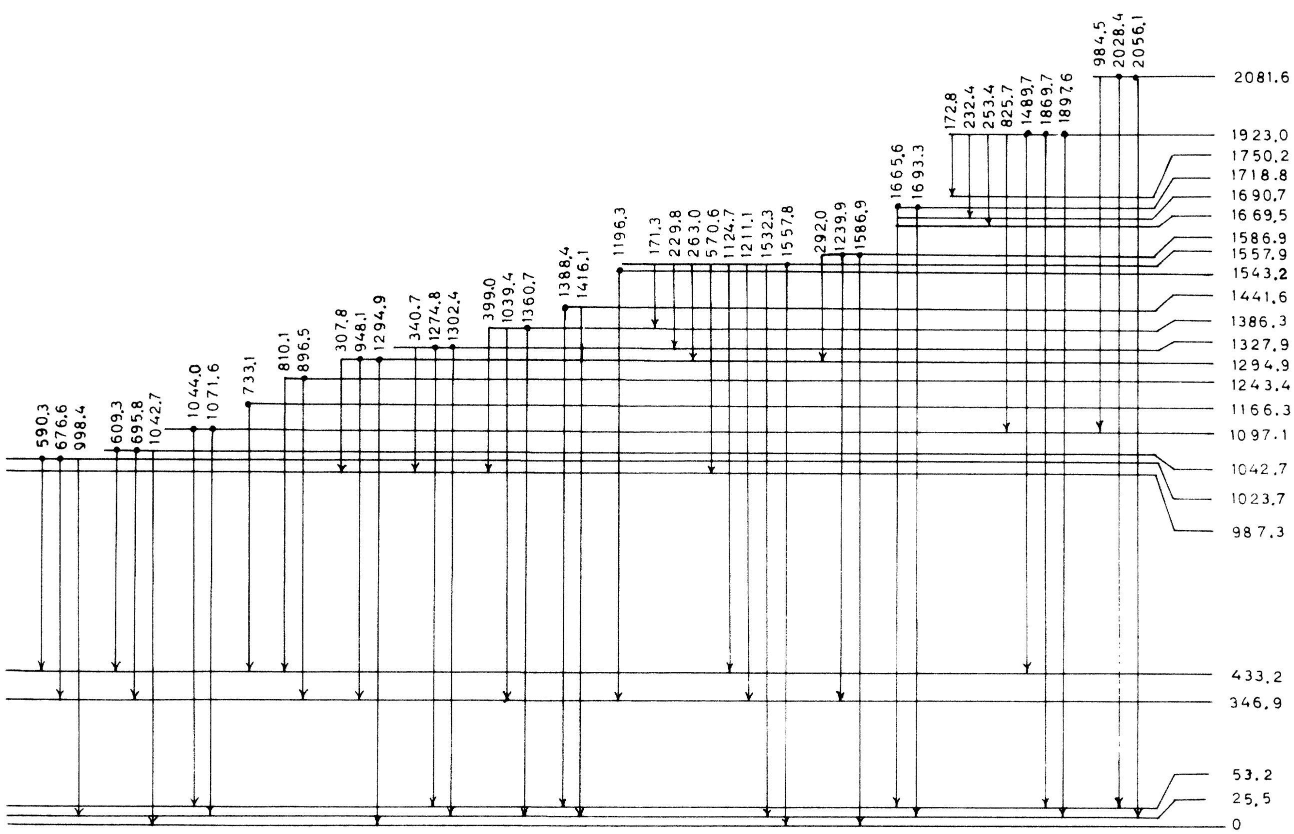

FIG. 2. Partial decay scheme of ^{105}Ag. Transitions marked with a dot were used to calculate lifetimes.

ton beams from the Chandigarh cyclotron. The target employed was a self-supporting foil of enriched ^{105}Pd which was thick enough to stop incident protons. The used Pd target material was of the following isotopic composition: 104, 1.38%; 105, 94.51%; 106, 3.81%; 108, 0.25%; 110, 0.04%. The target foil was mounted on a carbon ring and was placed in a thin walled steel chamber having tantalum as an inner lining. The γ rays were detected in a 50 cm^3 Ge(Li) detector having 2.0 keV resolution at 1.3 MeV. Singles γ-ray spectra were recorded at 90°, 75°, 60°, 45°, 30°, 15°, and 0° with respect to the beam direction. Further details of the experimental arrangement and method of analysis are given in our earlier publication.[8]

The experimental values of the attenuation factor $F(\tau)$ for different γ rays were calculated from the slopes of straight lines which were least squares fits to the experimental data, using the relation

$$E_\theta = E_{90^\circ}[1+\beta(0)F(\tau)\cos\theta] ,$$

where E_θ is energy of the gamma ray at an angle θ from the beam direction and $\beta(0)$ is the velocity of recoiling nuclei in the forward direction (along the beam axis). As the beam energies were close to threshold for most of the levels, the (p,n) reaction is predominantly a compound nucleus one; therefore, with a thick target this would lead to a symmetric neutron angular distribution about 90° in the c.m. system, resulting in an average neutron velocity in the beam direction of zero. It is therefore safe to assume that the mean forward recoil velocity of the ^{105}Ag nuclei is just the c.m. velocity.

Theoretically, the quantity $F(\tau)$ as a function of mean nuclear lifetime was calculated for ^{105}Ag recoiling in ^{105}Pd baking using the stopping power theory of Lindhard *et al.*,[9] taking the Blaugrund approximation[10] for the effect of nuclear scattering into account. In these calculations, the target thickness was taken into account explicitly by dividing the target into ten layers. The effect of cascade feeding was taken into account by the method of Hoffman *et al.*[11] The plots of E_θ versus $\cos\theta$ and their best fits for some of the γ rays are shown in Fig. 1.

The excitation energy and lifetime of the levels are summarized in Table I. The errors in lifetimes correspond to the errors in the experimental values of $F(\tau)$. However, an additional error of up to 20% may be attributed to the results, due to the uncertainty in nuclear stopping power, which predominates at the recoil velocity ($\beta \simeq 0.1\%$) of ^{105}Ag nuclei for incident protons of 5.2 MeV. The partial decay scheme from the levels investigated in this work is shown in Fig. 2.

The authors are grateful to Professor H. S. Hans for fruitful discussions and encouragement during the course of this work.

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