Lifetime of the 724.3-keV level and shell-model intruder states in ^{109}Ag

R. A. Braga and R. W. Fink
School of Chemistry, Georgia Institute of Technology, Atlanta, Georgia 30332
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The half-life of the $\frac{3}{2}^+$, 724.3-keV level in ^{109}Ag, populated in the decay of ^{109}Pd, has been determined to be 3.2 ± 0.8 nsec. The observed lifetime and γ-ray branching supports the interpretation that the rotational band structure in the odd-mass Ag isotopes arises from the $g_{7/2}$ shell-model state.

[RADIOACTIVITY ^{109}Ag; measured γ-γ,β-γ delayed coin., $T_{1/2}$ of 724.3-keV level; enriched targets; Ge(Li), Ge(HP), and NE-111 plastic-scintillation detectors.]

The $g_{7/2}$ shell-model state is known to intrude across the $Z = 50$ shell closure[1] to appear in the odd-mass In isotopes as a rotational bandlike structure, coexisting with spherical hole states. Evidence that the $g_{7/2}$ "intruder band" lies closer to the Fermi surface in the odd-mass Ag isotopes than in the odd-mass In isotopes has already been recognized.[2–4]

Intruder bands exhibit certain distinct features; notably, long lifetimes for the bandheads (typically 5–130 nsec in In) and rotational characteristics including strong intraband transitions. They are believed[5] to play a critical role in the development of deformed nuclear shapes. In previous decay studies[2,6] of ^{109}Ag and ^{111}Ag, the low-spin members of the $g_{7/2}$ intruder band were identified, and a half-life of 16 nsec was obtained for the $\frac{3}{2}^+$, 376.7-keV bandhead level in ^{111}Ag.[2] Here, we report a determination of the half-life of the $\frac{3}{2}^+$, 724.3-keV level in ^{109}Ag populated in the decay of ^{109}Pd (13.43 h).

For the lifetime measurements, sources of ^{109}Pd were prepared in the Georgia Tech Research Reactor by the (n, γ) reaction on enriched ^{108}Pd. The lifetime of the $\frac{3}{2}^+$, 724.3-keV level was measured with a delayed coincidence technique employing state-of-the-art ARC (amplitude and risetime compensated) timing. Data acquisition consisted of multiparameter $\gamma\gamma t$ coincidences taken with a shielded Ge(HP)-Ge(Li) detector system (HP means highly purified), as well as $\beta\gamma t$ coincidences with a plastic scintillator NE-111 Ge(Li) system. Detector characteristics were: (1) Ge(Li), 1.72-keV full width at half maximum at 1332 keV; (2) Ge(HP), 475 eV at 122 keV; (3) NE-111 plastic, 2.54×5.08 cm ^{2} diam, RCA 8575 photomultiplier tube. A Nuclear Data ND-4420 multiparameter analyzer (MPA) system was used to acquire coincidences which were stored event by event on magnetic tape.

For both detector systems, the Ge(Li) detector provided the time-to-amplitude converter (TAC) start pulses, while the Ge(HP) or plastic detector provided the stop pulses. The lifetime of the 724.3-keV level was measured by gating the Ge(HP) detector on the 145.4-keV γ ray or by gating the plastic detector on the energy region 100–400 keV while gating the Ge(Li) detector on the 724.6-, 636.4-, 413.0-, and 309.3-keV γ rays. In the plastic detector, stop events could be supplied either by β or γ radiation that preceded the emission of γ rays deexciting the 724.3-keV level. The prompt TAC spectrum was obtained from the 6 psec 311.4-keV and 35 psec 415.0-keV levels in ^{109}Ag. The Ge(Li) energy gates were placed on the 415.0- and 311.3-keV γ rays while Ge(HP)

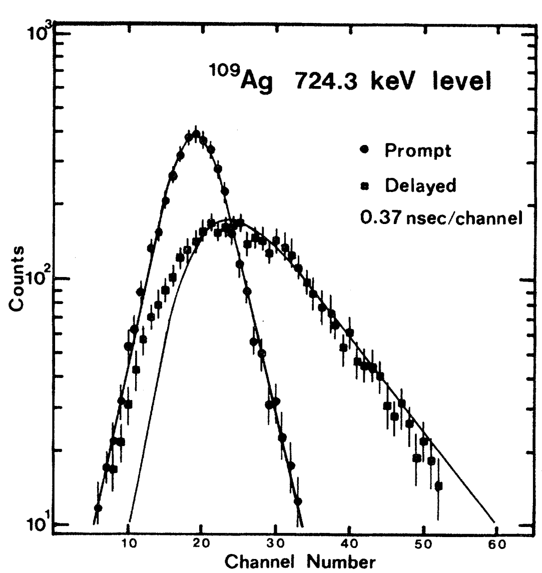

FIG. 1. Comparison of the area-normalized prompt coincidence curve with delayed coincidence curve from 724.3-keV level in ^{109}Ag. The solid lines represent the linear regression analysis fits to the prompt curve and to the delayed component of the delayed curve. The start events [Ge(Li) detector] are on the right; the stop [Ge(HP) or plastic detector] are on the left.

TABLE I. Transitions depopulating the 724.3-keV level in ^{109}Ag.

E_γ (keV)	309.1	413.0	636.0	724.3
J^π final	$\frac{5}{2}^-$	$\frac{3}{2}^-$	$\frac{7}{2}^+$	$\frac{1}{2}^-$
Multipolarity	$E1$	$E1$	$E2$	$E1$
Gamma branch	0.22	0.32	0.46	0.004
Partial $T_{1/2}$	14.5 nsec	10.0 nsec	6.9 nsec	800 nsec
Moszkowski[a] $T_{1/2}$	10.3 fsec	4.3 fsec	0.17 nsec	0.80 fsec
Hindrance (t_{obs}/t_{calc})	1.4×10^6	2.3×10^6	40	1×10^9

[a]S. A. Moszkowski, in *Alpha-, Beta-, and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (North-Holland, Amsterdam, 1965), Vol. 2, p. 863.

gates were placed on the 309.3- and 413.0-keV γ rays or on the energy region 300–800 keV in the plastic detector.

A centroid shift technique employing a first-moment analysis[7] was used to evaluate the TAC spectrum from the Ge(Li)-Ge(HP) system, while a deconvolution procedure utilizing linear regression analysis[8] was used on the Ge(Li)-plastic scintillator TAC spectrum (Fig. 1). In this figure the solid curve through the delayed TAC spectrum represents the delayed component and excludes the prompt component. This deconvolution procedure results in a half-life slightly longer than would be obtained from a slope analysis (as evident from the apparent deviation of the fit from the experimental data at longer times). This is a result of the fitting procedure in which the entire set of experimental data in the delayed time spectra is used, thereby giving less weight to the events of lower statistical quality at longer times.

The resulting values of the half-life, utilizing the two different coincidence systems with different analysis procedures, are in excellent agreement yielding an average value of 3.2 ± 0.8 nsec for the $\frac{3}{2}^+$, 724.3-keV level in ^{109}Ag. No measurable half-life for the 706.9-keV level, tentatively assigned as being the $\frac{1}{2}^+$ member of the $g_{7/2}$ band, was obtained. A summary of transitions depopulating the 724.3-keV level in ^{109}Ag is given in Table I. The observed hindrances are consistent with those obtained for transitions depopulating the $\frac{3}{2}^+$, 376.7-keV level in ^{111}Ag.[2]

As in the case of the $\frac{1}{2}^+$ and $\frac{3}{2}^+$ states in the odd-mass In isotopes, the measured $E1$ transition probabilities from the $\frac{3}{2}^+$ state in ^{109}Ag are an indication that this state is of different character than the lower-lying states. The rotational bandlike structure built upon these positive parity states in ^{109,111}Ag and $^{113-119}$In is associated with the $\frac{1}{2}^+$ [431] Nilsson state arising from the $g_{7/2}$ shell-model orbital. The $\frac{1}{2}^+$ [431] state is a rapidly descending level from the next major shell (hence, "intruder") which has a large slope, thereby cutting the Fermi level around $\epsilon=0.24$.

The present half-life measurement along with the previous results for ^{111}Ag supports the interpretation of the observed rotational band structure as arising from the $g_{7/2}$ shell-model intruder state.

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