Lifetime measurement of the $\pi g_{9/2}$ isomer in ^{79}As

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The lifetime of the 773 keV $\pi g_{9/2}$ isomer in ^{79}As has been measured to be $T_{1/2}=0.87(6)$ μs by taking coincidences between γ rays and projectilelike fragments produced in deep-inelastic collisions of ^{198}Pt $+^{76}$Ge (635 MeV). The $B(M2,9/2^+\rightarrow5/2^-)$ value for the 542 keV transition in ^{79}As is found to be 0.042(3) Weisskopf units (W.u.). An identification method of nuclei produced in deep-inelastic collisions is also described. [S0556-2813(98)05408-9]

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In the arsenic isotopes, $\pi g_{9/2}$ isomers thus far were found in the five odd-A nuclei from $A=69$ to 77. The existence of this isomerism raised the possibility that a similar situation could exist in ^{79}As. Previously, the excited states in ^{79}As were studied through the β decay of ^{79}Ge [1] and via the (α,p) transfer reaction [2]. In the β decay a 542-231 keV γ-ray cascade was observed, and the (α,p) experiment assigned the associated 231 keV and 773 keV levels as $\pi f_{5/2}$ and $\pi g_{9/2}$ states, respectively. These previous studies suggested that the 773 keV state in ^{79}As should be an isomer, but no lifetime measurement has yet been performed for it. In the present study, we have measured the half-life of the 773 keV state and have obtained the transition strength of the 542 keV $M2$ isomeric transition.

The experiments were carried out at the tandem booster facility of the Japan Atomic Energy Research Institute at Tokai [3]. A ^{198}Pt target, 95.7% enriched and 4.3 mg/cm^2 thick, was bombarded with beams of 635 MeV ^{76}Ge (experiment 1), 550 MeV ^{76}Ge (experiment 2), and 625 MeV ^{74}Ge (experiment 3). In each experiment, coincidences between the projectilelike fragment (PLF) and γ rays as well as between γ rays were taken with the isomer scope [4]; for both the PLF's and the γ rays, energy and time signals were registered event by event on tape. For details of the isomer scope and data analysis see Ref. [4].

The γ-ray cascade of the 542 and 231 keV transitions was observed in all three experiments listed above. We found the intensity ratio of the two γ rays to be $I_{542}/I_{231}=0.98(10)$, in agreement with expectations, but not sufficiently accurate to extract useful information on transition multipolarities. The lifetime of the 773 keV isomer was determined from the PLF-γ coincidence data obtained in experiment 1. Figure 1 shows the decay curves of the 542 and 231 keV transitions. These curves give the half-life of the isomer as

$$T_{1/2}(9/2^+,773\ \text{keV})=0.87(6)\ \ \mu\text{s},$$

and the strength of the isomeric transition as

$$B(M2,9/2^+\rightarrow5/2^-,542\ \text{keV})$$
$$=0.042(3)\ \ \text{Weisskopf units (W.u.)},$$

in good agreement with the results for the neighboring isotopes.

Independent of the literature data, information on the mass and atomic number of the 773 keV isomer can be extracted from the present experiment. Here, the dynamic features of deep-inelastic collisions have been exploited for identification of the PLF nuclei. The results used for this identification are as follows.

Experiment 1. The total PLF energy spectrum shows a wide humped distribution which peaks at a lower energy than the projectile energy. However, for an individual PLF isotope, selected by gating the PLF signal with the γ rays of a specific isomer decay cascade, the distribution is found to be significantly narrower. The difference between the PLF and the projectile energy gives a measure of the energy dumped in the collision for the nuclide involved. Figure 2 shows the energies of individual PLF species selected in this way, for previously known isomers observed in our experiments (for references, cf. figure caption), plotted vs the transferred mass. This is defined as $|\Delta Z|+|\Delta N|$ for a nucleus

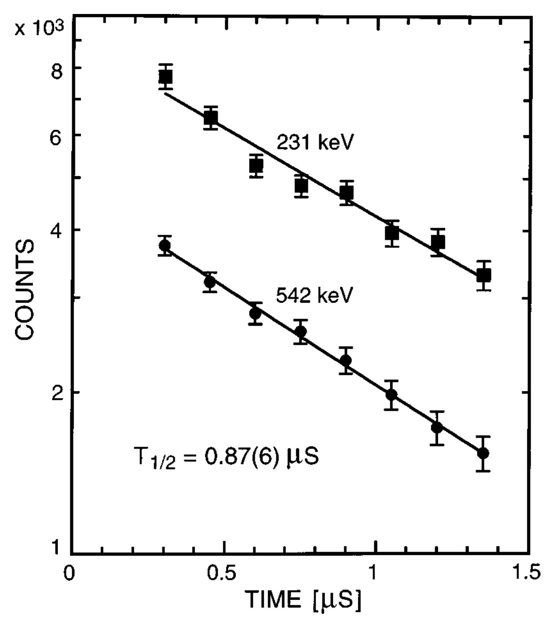

FIG. 1. Decay curves of the 542 and 231 keV γ rays from the 773 keV isomer.

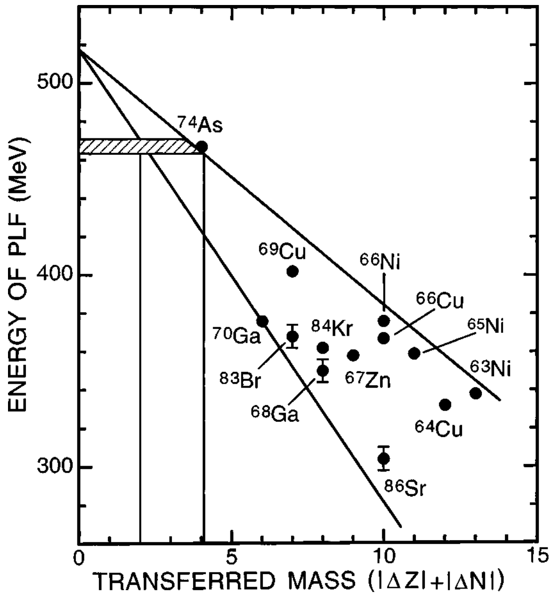

FIG. 2. A plot of the PLF energy vs the transferred mass, $|\Delta Z|+|\Delta N|$, obtained from previously known isomers produced in deep-inelastic collisions of 635 MeV ^{76}Ge with ^{198}Pt. The band indicates the PLF energy 466(3) MeV for the 773 keV isomer. This energy corresponds to $|\Delta Z|+|\Delta N|=2$, 3, 4. The isomer decay data are largely from Ref. [5]. In many cases the isomeric states do not appear in the level schemes since they are not populated in β decay, but may be found in the level list for the respective nuclide, where also the isomeric decay cascade and reference to the original work can be traced. The isomer decays for ^{65,66}Ni are from Ref. [6] and for ^{69}Cu from Ref. [4].

produced from $^{76}_{32}\mathrm{Ge}_{44}$. For the 542 and 231 keV γ rays, the PLF energy is 466(3) MeV, which indicates $|\Delta Z|+|\Delta N|=2-4$.

Experiment 2. The individual isomer yields of this experiment were compared with those obtained in experiment 1. These results revealed a dependence of the yields on the projectile energy. Figure 3 shows the yield ratios $I_\gamma(550\ \mathrm{MeV})/I_\gamma(635\ \mathrm{MeV})$ for the observed known iso-

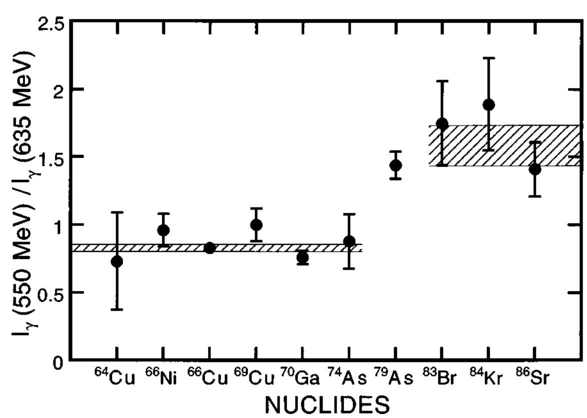

FIG. 3. Dependence of the isomer yields on the projectile energy. The yield ratios, $I_\gamma(550\ \mathrm{MeV})/I_\gamma(635\ \mathrm{MeV})$ were obtained from the γ-ray intensities of experiment 2 divided by those of experiment 1; the average values for $A<76$ and $A>76$ are also shown. The 773 keV isomer is denoted by ^{79}As. For references cf. caption to Fig. 2.

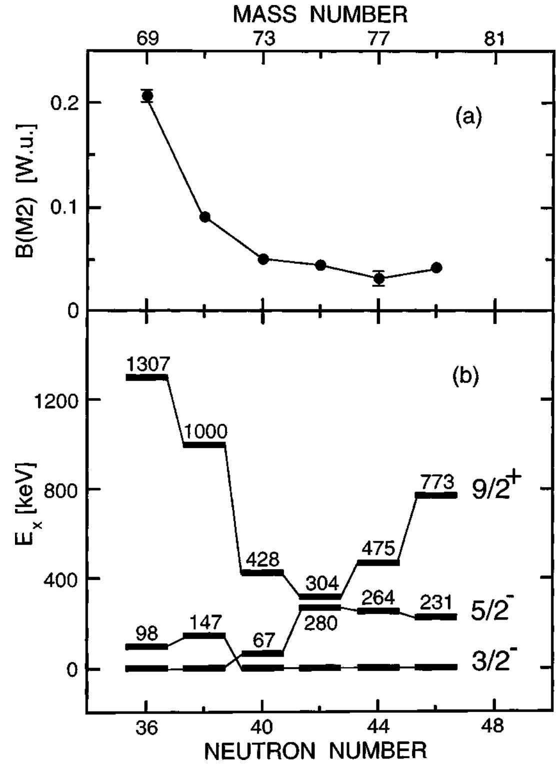

FIG. 4. Systematics of (a) $B(M2,9/2^+\rightarrow 5/2^-)$ values and (b) excitation energies of the lowest $3/2^-$, $5/2^-$, and $9/2^+$ states in odd As isotopes. The data are from Ref. [5] and the present work. More complete level systematics figures are presented in Refs. [1] and [2].

mers. It was found that these ratios are divided into two groups: one for light PLF's ($A<76$) and the other for heavy ones ($A>76$). At lower projectile energy the yields of the light PLF's decrease more strongly than those of the heavy ones. The yield ratio for the 773 keV isomer, denoted in Fig. 3 as ^{79}As, indicates that this isomer belongs to the latter group ($A>76$).

Experiment 3. The isomer yields measured with ^{74}Ge projectiles were compared with those obtained in experiment 1 with ^{76}Ge. It was found that the more neutron-rich nuclei had smaller yields when we used a ^{74}Ge beam. Thus, the yield ratios $I_\gamma(^{74}\mathrm{Ge})/I_\gamma(^{76}\mathrm{Ge})$ provided important information about the neutron number of the PLF. These ratios are 0.46(3), 0.37(5), and 0.44(4) for ^{86}Sr, ^{84}Kr, and ^{83}Br and 0.08(5) for the 773 keV isomer, which indicates that the N/Z ratio of the 773 keV isomer is larger than those of the former three nuclei.

The above results of experiments 1–3 confine the 773 keV isomer to a region of ten nuclides with $A>76$, located at the neutron-rich side, and with Z values from 31 to 34, including ^{79}As. An independent determination for the PLF Z value, which in principle is possible with a ΔE-E counter telescope, will reduce the number of candidates to 3. Such a measurement would be vitally important, if the 542 and 231 keV γ-ray cascade transitions were not known to be in ^{79}As.

As mentioned above, the isomeric $M2$ transitions between the $9/2^+$ and $5/2^-$ states were observed earlier in the odd As isotopes with $A=69-77$; for references cf. caption to Fig. 4. Their $B(M2)$ values, and the present result for ^{79}As, are plotted against the mass number in Fig. 4(a); the excitation energies of the lowest $3/2^-$, $5/2^-$, and $9/2^+$ levels, which should largely be of single proton character, are shown in Fig. 4(b). The energy of $9/2^+$ excitation decreases towards higher masses up to $A=75$, and for the same range the $B(M2)$ values show a similar tendency. For yet heavier masses, however, where the $9/2^+$ energy goes up again, the $M2$ strengths remain small and nearly constant. The $B(M2)$ values seem to relate to the configuration of the $5/2^-$ state as well as to the deformation of the nuclei. The $5/2^-$ levels are ground states in ^{69,71}As, but turn to excited states in $^{73-79}$As. This fact suggests that the $5/2^-$ states in $^{73-79}$As are mixtures of the configurations of $\pi f_{5/2}(\pi f_{5/2})^2_{I=0}(\pi p_{3/2})^2_{I=0}$ and $\pi f_{5/2}(\pi p_{3/2})^4_{I=0}$; in other words, the closure of the $\pi p_{3/2}$ orbital, $(\pi p_{3/2})^4_{I=0}$, is weak in $^{73-79}$As. Such a configuration mixing could reduce the $B(M2)$ values in $^{73-79}$As.

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