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A New High-Spin Isomer 2.3 d ^{198m}Au
and the ^{198}Au Level Structure*

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Abstract: The decay of a new high-spin isomer in ^{198}Au has been studied. A revised interpretation of the results of earlier (n, γ) and (d,p γ) studies is presented and shell-model assignments for the levels populated in the ^{198m}Au decay are proposed.

Most of the information now available on the ^{198}Au level structure has been obtained in extensive neutron capture γ -ray studies.⁽¹⁻³⁾ The level spectrum, including a negative parity first excited state at 55.2 keV, has been established mainly on the basis of energy sums and transition intensities.⁽⁴⁾ A 123 nsec isomer, de-exciting by a sequence of 97.2 (E1) and 214.9 (E2) keV transitions, has been studied in $^{197}\text{Au}(d,p\gamma)$ by Bonitz⁽⁵⁾ and in $^{197}\text{Au}(n,\gamma)$ by Löbner et al.⁽⁶⁾ Since the latter authors obtained some indication that the isomer de-excites through the 55.2 keV level, they placed the 123 nsec level at 367.3 keV, thereby accommodating a known primary capture γ -ray; J^π values of 1^- or 3^- were inferred.

In ^{196}Au , a 12^- isomer, arising from the coupling of an $h_{11/2}$ proton and an $i_{13/2}$ neutron, has been known for several years.⁽⁷⁻¹⁰⁾ More recently, we discovered a similar 19 h isomer in ^{200}Au , which decays predominantly by β^- emission to high-spin levels in ^{200}Hg .⁽¹¹⁾ In the

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course of a more detailed investigation of the $^{200\text{m}}\text{Au}$ decay using a gold source produced in 18-MeV deuteron bombardments of enriched ^{202}Hg , we observed 97.2 and 214.9 keV γ -rays decaying with a half-life of about 50 hours. In order to determine the correct mass assignment, targets of enriched ^{200}Hg (88.9%), ^{202}Hg (76.8%) and ^{204}Hg (68.6%) were separately bombarded with 18 MeV deuterons and the gold activities were chemically extracted. Subsequent γ -ray measurements showed clearly that the intensities of the 97.2 and 214.9 keV γ -rays were directly proportional to the ^{200}Hg abundances in the target materials; the relative intensities of the 412 keV γ -ray (from $^{198\text{g}}\text{Au}$ decay) and the 97 and 215 keV γ -rays did not vary with target composition. The new activity was therefore assigned to $^{198\text{m}}\text{Au}$ and the half-life was determined to be 2.27 ± 0.05 d. Isomer ratio measurements for the production of $^{196\text{m}}\text{Au}/^{196\text{g}}\text{Au}$, $^{198\text{m}}\text{Au}/^{198\text{g}}\text{Au}$ and $^{200\text{m}}\text{Au}/^{200\text{g}}\text{Au}$ in the deuteron bombardments showed that in all three cases, about 7% of the total (d, α) reaction cross-section leads to population of the high-spin isomer. This result lends support to the view that $^{198\text{m}}\text{Au}$ and $^{200\text{m}}\text{Au}$ are analogues of the 12^- isomer in ^{196}Au .

A γ -ray spectrum of the Au source prepared from the enriched ^{200}Hg target is shown in Fig. 1. An analysis of sequential γ -ray spectra showed that the four strong γ -rays 97.21, 180.31, 204.10 and 214.89 keV occur in the decay of $^{198\text{m}}\text{Au}$. In addition, the broad photopeak at ~ 333.7 keV was resolved into a strong 333.8 keV component from 2.3 d $^{198\text{m}}\text{Au}$ decay and a weaker 333.0 keV component from 6.2 d ^{196}Au . A particularly careful but unsuccessful search was made for a 55.2 keV γ -ray; the maximum possible intensity of such a γ -ray is less than 1% of the 97.2 keV γ -ray intensity. Since the total conversion coefficient for the 55.2 keV transition is known to be about 16, the present results rule out the possibility that

the 97, 215 keV cascade populates the 55 keV level. The energies and relative intensities of the γ -rays assigned to ^{198m}Au decay are listed in Table 1.

Gamma-gamma coincidence measurements were also performed using two Ge(Li) detectors. It was found that the 180 and 204 keV γ -rays are in prompt coincidence, and that both transitions are in delayed coincidence with the 97 and 215 keV transitions de-exciting the 123 nsec level. The 334 keV transition is not coincident with the 180 and 204 keV γ -rays but occurs in a weaker decay branch into the 123 nsec level.

The combined data from the present work and from the (n,γ) studies indicate that the 123 nsec lifetime must be associated with a positive parity level at 312 keV which de-excites by an E1 transition to a negative parity level at 215 keV; the proposed J^π values of 5^+ and 4^- , respectively, are consistent with the fact that neither level is populated by a primary capture γ -ray. The multipolarities of the 180 and 204 keV transitions have not been experimentally determined but intensity balance requirements suggest rather strongly that they are E2 and M1 respectively. When these multipolarities are assumed, the transition intensities shown in Table 1 are obtained. Not only are the intensities of the 180 and 204 keV transitions closely equal but a satisfactory intensity balance is achieved at the 312 keV level, regardless of the choice of E2, M1 or E1 multipolarity for the weaker 334 keV transition.

Further insight into the nature of the ^{198}Au levels can be obtained by considering the main de-excitation path in the ^{196m}Au decay (Fig. 2 (a)). In proposing this scheme, Wapstra et al ⁽⁹⁾ pointed out that all their data were equally consistent with either E2 or E3 multipolarity assignments for the 85 keV transition; they therefore suggested the alternative decay

scheme shown in Fig. 2 (b) and commented that ℓ -forbiddenness might account for the highly hindered character of the unobserved E1 isomeric transition. From our results it seems virtually certain that just such an ℓ -forbidden E1 isomer occurs in the ^{198m}Au decay and the proposed partial decay scheme is shown in Fig. 2 (c), together with shell-model assignments for the levels which are consistent with all the observations. The 97 keV E1 transition is retarded by a factor of 10^6 with respect to the Weisskopf estimate; this high degree of hindrance is undoubtedly due to the ℓ -forbidden nature of the $(d_{3/2} \ i_{13/2})^{5+} \longrightarrow (d_{3/2} \ f_{5/2})^{4-}$ single particle transition.

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References

- 1) B. Hamermesh, J. E. Monahan, R. K. Smither, Ann. Phys. (N.Y.) 13(1961) 307.
- 2) O. A. Wasson, R. E. Chrien, M. R. Bhat, M. A. Lone, M. Beer, Phys. Rev. 173 (1968) 1170.
- 3) T. v. Egidy, E. Bieber, T. W. Elze, Z. Physik, 195(1966) 489.
- 4) Nuclear Data 6 (1971) no. 4.
- 5) M. Bonitz, Nucl. Phys. A118 (1968) 478.
- 6) K. E. G. Löbner, J. Klockner, H. Schimmer, P. Kienle, Z. Phys. 235(1970)254.
- 7) R. Van Lieshout, R. K. Girgis, R. A. Ricci, A. H. Wapstra, Nucl. Phys. 25 (1959) 703.
- 8) Y. W. Chan, W. B. Ewbank, W. A. Nierenberg and H. A. Shugart, Phys. Rev. 127 (1962) 572.
- 9) A. H. Wapstra, P. F. A. Goudsmit, J. F. W. Jansen, J. Konijn, K. E. G. Löbner, G. J. Nijgh, S. A. de Wit, Nucl. Phys. A93 (1967) 527.
- 10) F. Bacon, G. Kaindl, H. E. Mahnke, D. A. Shirley, Phys. Letters 37B (1971) 181.

- 11) K. Sakai, P. J. Daly, Nucl. Phys. A118 (1968) 361.

Table 1. Transitions observed in the decay of 2.3 d $^{198\text{m}}\text{Au}$

E_{γ} (keV)	Relative γ -ray Intensity	Multi- polarity	Relative transition Intensity
97.21 ± 0.05	91 ± 4	E1	130 ± 6
180.31 ± 0.05	66 ± 5	(E2)	99 ± 8
204.10 ± 0.06	54 ± 4	(M1)	100 ± 7
214.89 ± 0.05	100	E2	127
333.82 ± 0.15	20 ± 5		

Figure Captions

Fig. 1. The $^{198\text{m}}\text{Au}$ γ spectrum

Fig. 2. (a) and (b). The alternative decay schemes⁽⁹⁾ for $^{196\text{m}}\text{Au}$;
(c). The proposed $^{198\text{m}}\text{Au}$ decay scheme.

(a)

(b)

(c)

Assignments

π ν