Low-lying Levels in Odd-mass Au Nuclei

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The low energy levels of ^{197}Au and ^{199}Au have been investigated by means of a high resolution double focusing beta-ray spectrometer. The conversion electron ratios as well as the K-conversion coefficients of low-lying transitions were determined. The K-internal conversion coefficients of the 191 keV transition in ^{197}Au indicated no EO contribution. The level structure of the lower excited states in ^{197}Au and ^{199}Au are discussed in terms of existing nuclear models.

Introduction

The level schemes of odd-mass gold nuclei are of theoretical interest. Kisslinger and Sorensen[1] have calculated the energy levels taking into account the residual nuclear interactions. This suggests that the level schemes of odd-mass gold nuclei can be described as due to the coupling of the odd particle motion with the surface vibrations of the even core. The low-lying levels of odd-mass isotopes of Ag, Au and Tl have been interpreted by de-Shalit[2] as the coupled states of a single odd particle to the excited core. Alga and Ialongo[3] have calculated the energies and the transition probabilities of low-lying levels in ^{197}Au by using the intermediate coupling model with appropriately assumed values for several parameters. The low-lying level schemes of ^{193}Au, ^{195}Au, and ^{197}Au are found to be similar, but that of ^{199}Au according to previous workers differs considerably. Since the neutrons are being filled pairwise into the next major shell ($N = 126$) the addition of two neutrons to ^{197}Au should not have a very large effect on the motion of 79th proton in the lower major shell ($P = 82$). Therefore one should expect a low-lying level scheme for ^{199}Au similar to that of the other odd-mass gold nuclei.

Recently we have studied[4, 5, 6] the level schemes of ^{197}Au and ^{199}Au. However, we felt that more information on low-lying levels in this interesting region could be obtained if the measurements were carried out with enriched isotopes and improved techniques. In view of such interest, it was decided to examine experimentally the low-lying excited states of ^{197}Au and ^{199}Au and to compare them with the theoretical predictions.

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Experimental Procedures

The excited levels in ^{197}Au and ^{199}Au were studied from the decay of 86 min ^{197m}Pt, 18 h ^{197}Pt and 30 min ^{199}Pt. Energies and relative intensities of conversion electrons were measured by means of a high resolution iron-free double focusing beta-ray spectrometer[7] ($\varrho_0 = 50$ cm). With this instrument relative momentum measurements could be made with an accuracy of a few parts in 10^5. With a 1.2×2 cm^2 source and 2 mm detector slit a resolution of 0.15% was obtained. The detector employed in the present studies was a G.M. counter with a 1.6 mg/cm^2 mica end window.

The platinum activities were produced by thermal neutron bombardment of natural platinum and on enriched sample of ^{198}Pt ($\sim 35\%$) over a period of 5 hours and 48 hours in the U.A.R. Reactor at Inchass. The flux was about 10^{13} neutrons/cm^2 sec. For the internal conversion studies, platinum was uniformaly sputtered on aluminium foil of thickness ~ 1 mg/cm^2. The sputtered material was distributed in a rectangular area (0.2×2 cm^2). The thickness of the material deposited was estimated to be $\sim 100\,\mu$g/cm^2.

The internal conversion spectra for lower transitions in ^{197}Au and ^{199}Au, Fig. 1, were studied carefully in the double focusing beta-ray spectrometer. The measurements of higher transitions have been previously reported[4, 5, 6] by the author. All of the conversion lines were measured at least twice with different sources. Two transitions, at 77 and 191 keV, were found to coincide in energy with transitions in ^{197}Au and ^{199}Au. To obtain the intensities of the corresponding conversion lines in ^{199}Au, their decay was followed and the contribution from ^{197}Au could thus be subtracted. A typical L-conversion spectrum for the 77 keV transition in ^{197}Au is shown on Figure 2. It can be seen that L_I, L_{II} and L_{III} lines are almost completely resolved. The intensity of each line was determined by summing all pure counts reduced to the equal

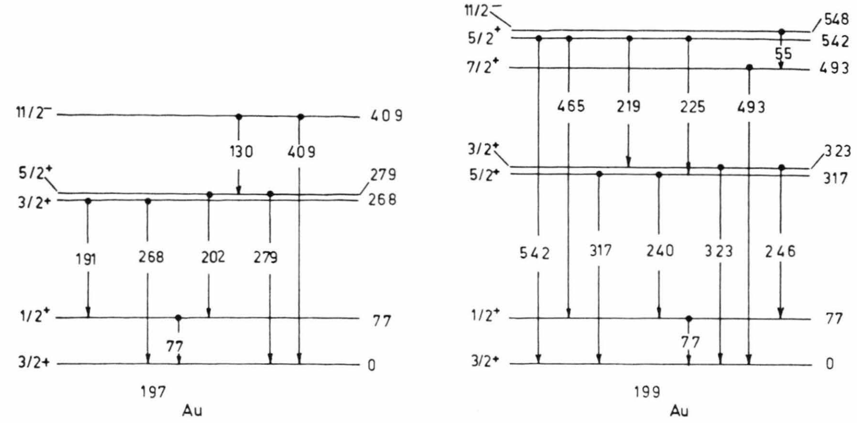

Fig. 1. Low-lying energy levels of ^{197}Au and ^{199}Au.

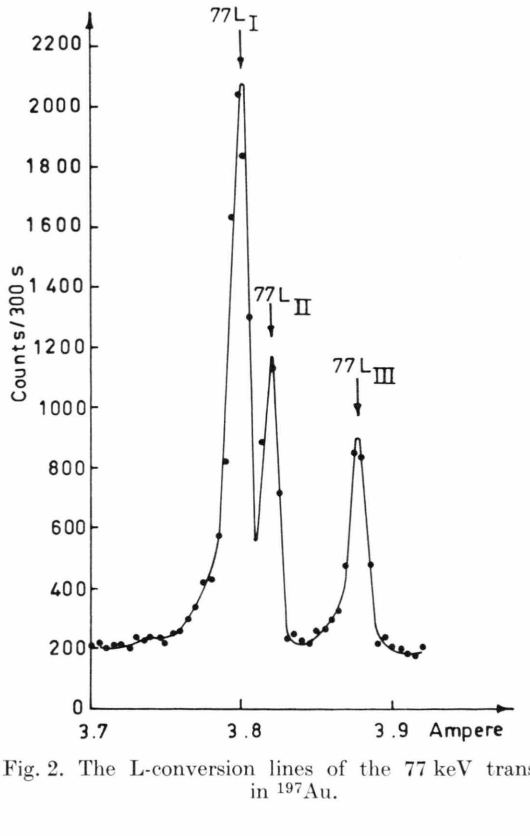

Fig. 2. The L-conversion lines of the 77 keV transition in ^{197}Au.

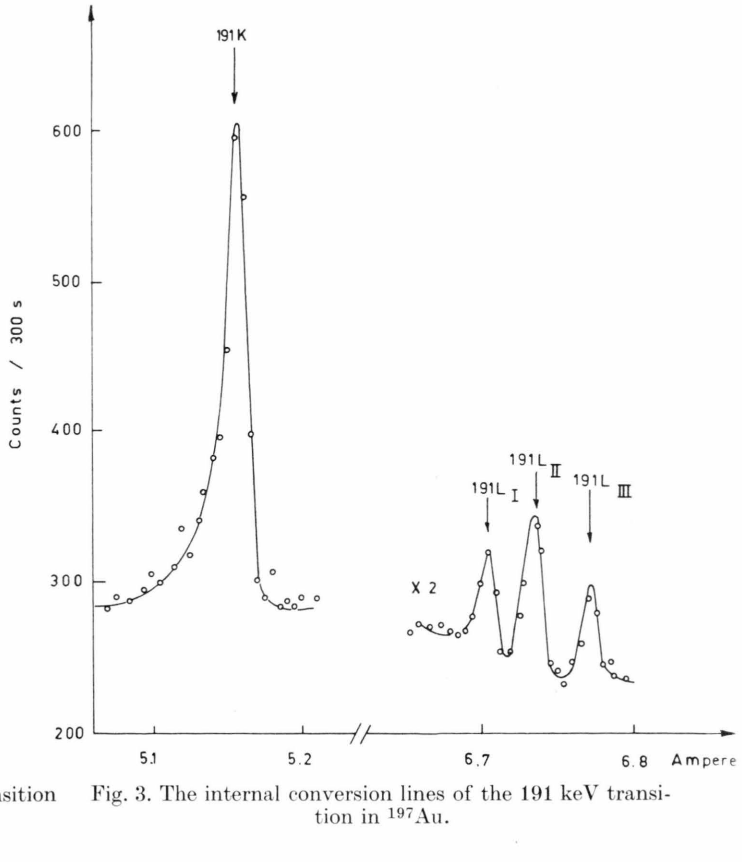

Fig. 3. The internal conversion lines of the 191 keV transition in ^{197}Au.

momentum intervals. The K and L conversion lines for the 191 keV transition in ^{199}Au are presented on Figure 3. In the present investigation, the K-conversion line of most of the transitions could be measured. On Fig. 4 the K-conversion lines of the 246 and 317 keV transitions in ^{199}Au are shown.

The K-conversion coefficients are obtained by combining the conversion electron intensities and the gamma-ray intensities from our previous[5,6] measurements. Normalization was made assuming that the 185.8 keV transition in ^{199}Au is pure E 2, and that the 542 keV transition has an M 1 character. Thus the K-conversion coefficients of several

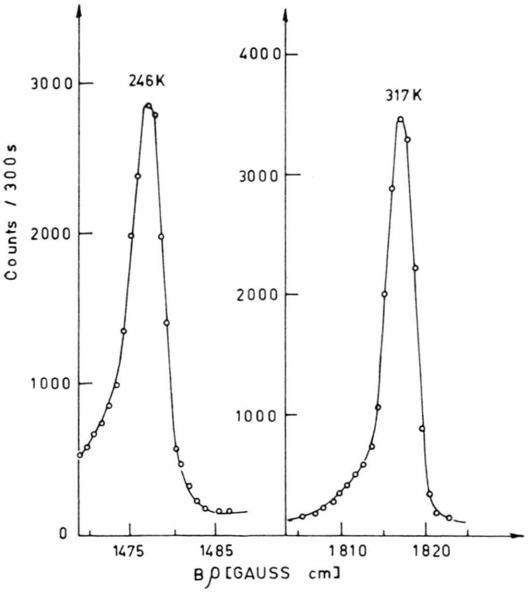

Fig. 4. The internal K-conversion lines of the 246 and 317 keV transition in ^{199}Au.

transitions in both ^{197}Au and ^{199}Au are determined and listed in Table 1. Multipolarities of gamma-rays are obtained by comparing the experimental conversion coefficients with the theoretical values [8].

Table 1. K-conversion coefficients of low-lying transitions in ^{197}Au and ^{199}Au.

Nucleus	Transition energy (keV)	Experimental K-conversion coefficients	Multipolarity
^{197}Au	191.4	0.915 ± 0.098	M 1 + 4% E 2
	268.2	0.215 ± 0.026	M 1 + E 2
	279.3	0.305 ± 0.31	M 1 + 12% E 2
	409.2	2.124 ± 0.258	M 4
^{199}Au	219.3	0.52 ± 0.5	M 1 + 27% E 2
	225.6	0.49 ± 0.06	M 1 + 25% E 2
	246.4	0.45 ± 0.04	M 1 + 8% E 2
	317.0	0.194 ± 0.015	M 1 + 23% E 2
	465.4	0.018 ± 0.003	E 2
	493.3	0.019 ± 0.003	E 2
	542.5	0.059 ± 0.007	M 1

Results and Discussion

The energy levels of ^{197}Au were constructed on the basis of the accurate energy measurements of our previous work [5]. For all excited levels, spin and parity assignments have been based on the experimental data of the present as well as our previous work. The first excited state at 77 keV with spin and parity 1/2 + has been discussed earlier [5]. In the conversion electron spectrum the L_I, L_{II}, L_{III}, M and N lines of the 77 keV transition were identified and a predominant M 1 character with a small E 2 admixture has been assigned for this transition. The mixing ratio was calculated from the $L_I + L_{II}/L_{III}$ subshell ratio. It is in good agreement with the recent result obtained by Krpic et al. [9], where 10% E 2 admixture was found. The internal K-conversion coefficient of the 191 keV transition $\alpha_K = 0.915 \pm 0.098$ obtained previously [5] agrees with the value quoted by Krpic et al. [9] $\alpha_K = 0.86 \pm 0.03$. The mixing ratio δ^2 = E 2/M 1 has been estimated from the K-conversion coefficient and the conversion electron ratio, to be 0.04. However, the value reported by Krpic et al. [9] is $\delta^2 = 0.17 \pm 0.04$ and the calculated value according to the De-Shalit [2] model is 0.04 ± 0.02. By inspecting these values we can conclude that our result is in good agreement with the De-Shalit model, and the internal conversion result does not support the previous suggestion of an E 0 contribution to the 191 keV transition. The 3/2 + and 5/2 + assignments to the levels 268 and 279 keV respectively were proved to be evident and discussed in our previous work [5]. The meta stable state of ^{197}Au has been assigned as 11/2 −, as supported by the decay of the 409 keV M 4 gamma ray to the ground state and of the 130 keV E 3 gamma ray to the 279 keV (5/2 +) level in ^{197}Au.

The gamma rays from the decay of ^{199}Pt to levels in ^{199}Au have been carefully studied and the spin assignment of levels in ^{199}Au were confirmed. The ground state of ^{199}Au was shown [6] to be 3/2 + and the first excited state at 77 keV has been assigned 1/2 +. The states at 317, 323, 493, 542, and 548 keV were assigned as 5/2 +, 3/2 +, 7/2 +, 5/2 + and 11/2 − respectively. These assignments are all consistent with the present multipolarity data of gamma-rays feeding and de-exciting the mentioned levels. Higher levels in ^{199}Au were studied and discussed briefly in our previous work [6].

Spin 1/2 + has been assigned to the first excited state in ^{193}Au, ^{195}Au, ^{197}Au and ^{199}Au on sufficient experimental evidence [10]. The 1/2 + state could be described as due to the $S_{1/2}$ proton configuration. Then the transition from the first excited state $S_{1/2}$ to the ground state $d_{3/2}$ is expected to be an l-forbidden M 1 transition. From the lifetime measurements of the first excited states of ^{193}Au, ^{195}Au, ^{197}Au and ^{199}Au such transitions are identified[10]. It has been shown by De-Shalit[2] that the lowest excited states of odd-proton nuclei in the Au-Tl region may be interpreted as members of the multiplet of states arising from a coupling between the particle forming the ground state, and the collective 2 + excitation of the "core" of these nuclei. It was shown[10] that the systematic behaviour of the E 2 transition probability between the first excited state and the ground state in odd-proton Au and Tl nuclei is reproduced rather well by this model, while the poor agreement is observed with the calculations of Kisslinger and Sorensen[1] with a pairing plus quadrupole residual force, in which the 1/2 + state is given predominantly as $S_{1/2}$.

In the Au nuclei four excited states with the spins 1/2, 3/2, 5/2 and 7/2 should be formed by coupling the $d_{3/2}$ particle of the ground state to the 2 + excitation of the core. Thus it appears that the simple core excitation model has to be modified in order to account for the magnetic properties of the Au isotopes. It is likely that the mixing with the $d_{5/2}$ and $S_{1/2}$ single-particle states expected at low energy must be considered. An additional 5/2 + state was found at 542 keV in ^{199}Au. Since the ground state decay is somewhat favoured in comparison with other decay modes, one may tentatively classify this state as the $d_{5/2}$ state. However, there is no radical difference between the decay mode of this state and the 5/2 + state at 317 keV which may indicate a strong mixing of these states.

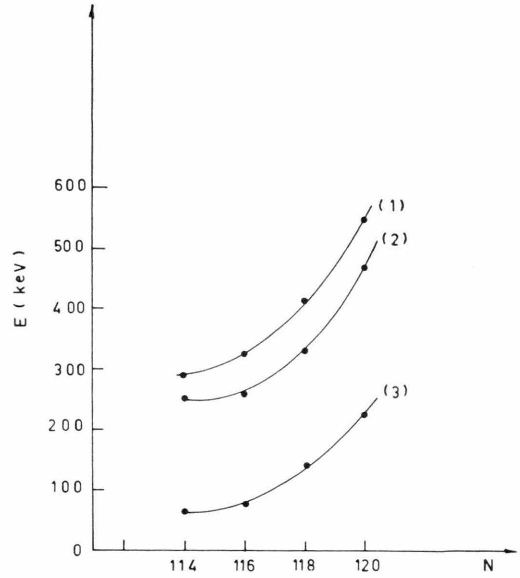

Fig. 5. The spacing between the $h_{11/2}$ and $d_{3/2}$ and $S_{1/2}$, $d_{3/2}$ single (proton) particle states-odd-mass Au nuclei. (1) indicates $h_{11/2} \rightarrow d_{3/2}$ (single particle), (2) indicates $h_{11/2} \rightarrow S_{1/2}$ (single particle), (3) indicates $h_{11/2} \rightarrow d_{3/2}$.

In this region an expected state $h_{11/2}$ in the shell model for the 79th proton is observed in ^{193}Au, ^{195}Au and ^{197}Au at 290, 318 and 409 keV respectively. The energy 548 keV found for the 11/2 − state in ^{199}Au fits well to this rising trend. It is interesting to show, Fig. 5 the smooth variation of the spacing between the $h_{11/2}$ and $d_{3/2}$ and $S_{1/2}$ and $d_{3/2}$ single (proton) particle states, as one increases the number of neutrons in the gold nuclei. Such smooth variation can possibly be accounted for by taking into account the residual nuclear interactions.

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