for the doublet energies. It seems probable that the original values of Van Patter *et al.* are too high, and that the actual values for the doublet energies may be lower by about 5 keV than the average values including Van Patter's measurement.

The value of 6.792±0.006 MeV that we obtain for the energy of the Be^{11} gamma ray is in agreement with the excitation energy for the upper level based on the reaction Q-value data cited above. It is concluded that the beta decay of Be^{11} populates the upper member of the doublet.

The previous work of Wilkinson and Alburger shows that the beta-ray branches for the Be^{11} decay to the doublet and to the 7.99-MeV states of B^{11} are allowed. As discussed earlier, the 6.804-MeV state is $\frac{1}{2}^+$ or $\frac{3}{2}^+$, and the 7.99-MeV state is $\frac{3}{2}^+$ from the pair spectrometer and angular-distribution measurements discussed above. The parity of Be^{11} must therefore be even. This confirms the shell-model calculation of Talmi and Unna,[2] as well as their interpretation of the original Be^{11} decay-scheme data, and agrees with the conclusion of Donovan *et al.*[3]

The upper limit[1] on the beta-ray branch to the 6.752-MeV member of the B^{11} doublet corresponds to a lower limit of 6.9 on the logft value of this transition. This is consistent with a forbidden beta decay between the even-parity Be^{11} ground state and the 6.752-MeV level which is most probably $\frac{7}{2}^-$.

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Nuclear Transitions in Au^{197}†*

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The energy of the hardest gamma ray emitted following β^- decay of the ground state of Pt^{197} (18 h) has been measured in a lithium-drifted germanium detector to be 268 keV. A 279-keV gamma ray was resolved which decayed in intensity with the 78-min half-life of the isomeric level of Pt^{197}. The K-shell conversion coefficient of the 191-keV transition has been experimentally determined as 1.59±0.07, suggesting an $E0$ component, and that the spin and parity of the 268-keV level in Au^{197} are $\frac{1}{2}+$. Previously reported gamma rays in the decay of these platinum isomers at 155 and 202 keV are shown to arise from the presence of Au^{199}, formed in the β^- decay of Pt^{199}.

INTRODUCTION

NUCLEAR states of Au^{197} are excited in β^- decay[1–4] of Pt^{197}, orbital electron capture decay[5–8] of Hg^{197} and Hg^{197m}, and by Coulomb excitation[9–12] of gold. The known data are summarized in the disintegration scheme of Fig. 1. The present investigation concerns the properties of the nuclear transitions in gold which follow β^- decay of Pt^{197}.

The 18-h Pt^{197} and its 78-min isomer were produced in successive irradiations of metallic platinum in the Kansas State University Triga Mark II reactor. Each exposure was of duration one hour, and the platinum targets were enriched in Pt^{196} to an extent of 65.55%. Owing to the short time of irradiation, long-lived platinum activities were suppressed.

268- and 279-keV Transitions

The unconverted quanta emitted in decay of Pt^{197} and Pt^{197m} were observed in a lithium-diffused germanium detector of depletion layer thickness two millimeters with a reverse bias of 50 V at the temperature of liquid nitrogen. The resolution was 5.5 keV, full width at half-maximum, this limitation imposed by the electronic system. The data so obtained are shown in Fig. 2, where full energy peaks at 268 and 279 keV are seen to be clearly resolved. The 268-keV peak was found to decay with a half-life of 18 h, while the

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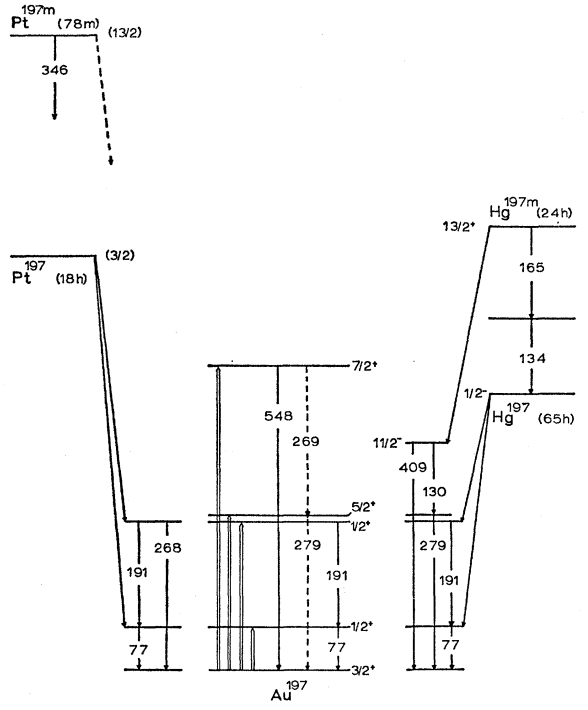

FIG. 1. Nuclear energy states of Au^{197}.

279-keV peak decayed with the half-life of the 78-min isomer. These results confirm the conclusion of Helmer[3] that the most energetic quantum emitted by the 18-h activity has an energy of 268 keV. That the 279-keV gamma ray decays with the 78-min period has been reported recently by Griesacker and Roy.[4]

K-SHELL CONVERSION COEFFICIENT OF THE 191-keV TRANSITION

To measure the K-shell conversion coefficient, gold was chemically separated from reactor-irradiated platinum.

The scintillation spectrum of single counts observed with a NaI(Tl) crystal, of the softer gamma rays of Pt^{197}, is shown in Fig. 3 (broken line). The gamma rays of energies 77 and 191 keV are clearly seen. A coincidence experiment was performed to measure the K-shell conversion coefficient of the 191-keV gamma ray. A slow-fast coincidence circuit of resolving time 10^{-7} sec was employed. The total coincidence spectrum (genuine plus chance) and the chance spectrum were observed simultaneously in two halves of the memory of the multichannel analyzer. The two counters were shielded from each other by intervening lead, cadmium, and copper, and the data were collected for two angular separations of the axes of the counters, 22 and 75 deg. The gate pulses were those lying between the tenth and sixtieth channel, including the 77-keV gamma ray, the 67-keV K x rays of gold which follow internal conversion of the 191-keV gamma ray, and the escape peaks of both. The pulse-height spectrum obtained in the analyzing crystal is shown in Fig. 3 (unbroken line). The K-shell conversion coefficient of the 191-keV transition can be obtained by taking the ratio of the area under the (x-ray)−(gamma-ray) peak between channels 10 and 60 to the area under the full energy peak at 191 keV. However, certain corrections must be applied to the data of Fig. 3 before calculation of the ratio. The area of the peak between channels 10 and 60 must be divided by two, because both the gating counter and the analyzing counter are counting both K-shell x ray and 77-keV gamma ray. The calculated area ratio was further corrected for fluorescence yield, detection efficiencies, and absorption of the gamma rays in carbon, aluminum, and aluminum oxide between source and crystal. This latter correction was determined experimentally. It has been found important always to make an experimental determination of the absorption correction for the particular geometry involved, rather than to calculate it from the absorber thickness and tabulated absorption coefficients, which apply to well collimated beams. Failure to follow this procedure led to "overcorrection" of other data[1] and thus to too large a value of $\alpha_K(191)$. For the angular separations of 75 and 22 deg, $\alpha_K(191)$ was computed to be 1.59 ± 0.07. The dimensions of the display crystal were 2.5×3.75 cm. Its gamma-ray detection efficiencies for the two angles of observation and associated source-to-detector distances were determined from tabulated values. The K-shell fluorescence yield of gold was taken to be 0.953. Earlier experimentally determined values of the K-shell conversion coefficient of the 191-keV transition are shown in Table I.

TABLE I. Previously measured values of the conversion coefficient of the 191-keV transition.

$\alpha_K(191)$	Reference
1.7	5
0.90 ± 0.10	6
2.5	1
0.65 ± 0.15	8
$2.0\ \pm0.5$	2

The K-shell conversion coefficient for $M1$ and $E2$ transitions of energy 191 keV have been calculated theoretically to be[13] 0.95 and 0.185, and[14] 0.87 and 0.185. The theoretical values of the conversion coefficient show that the 191-keV transition cannot be classified as $M1$ or $E2$ or any mixture thereof, if the presently measured value of $\alpha_K(191)$ is accepted. The large value of the conversion coefficient can be explained

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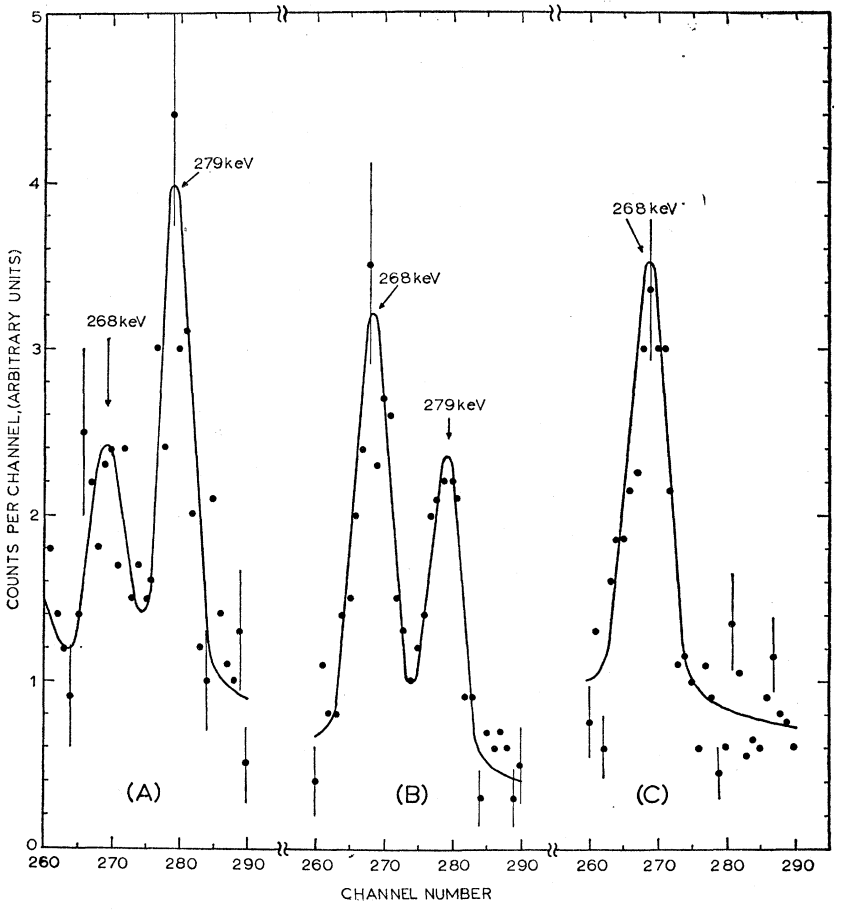

FIG. 2. Relative intensities of the 268- and 279-keV gamma rays. Curve (A) at time zero; curve (B) three hours later; curve (C), 22.5 h after curve A. Time zero occurs 2.5 h after removal of the irradiated target material from the reactor. The detector was of lithium-drifted germanium.

by the presence of an $E0$ component, as already suggested.[15]

It has been proposed[16] that the levels in Au^{197} at 77, 268, 279, and 548 keV have spins and parities $\frac{1}{2}+$, $\frac{3}{2}+$, $\frac{5}{2}+$, and $\frac{7}{2}+$, respectively, according to a model which couples the $d_{3/2}$ odd proton of Au^{197} to an excited

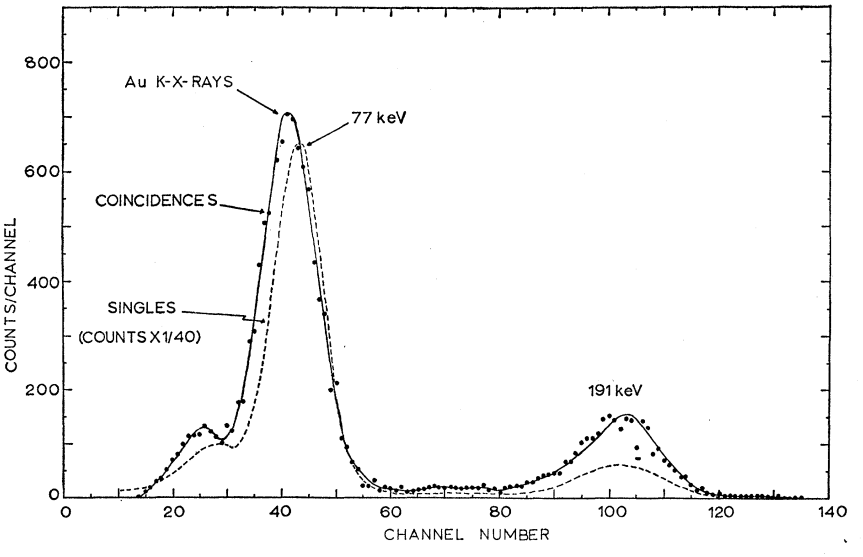

FIG. 3. Broken line is pulse-height spectrum of the softer quanta emitted in decay of Pt^{197}. Unbroken line is spectrum of radiations coincident with 77-keV gamma ray and K-shell x rays of Au^{197}. The angular separation of the axes of the counters was 22 deg.

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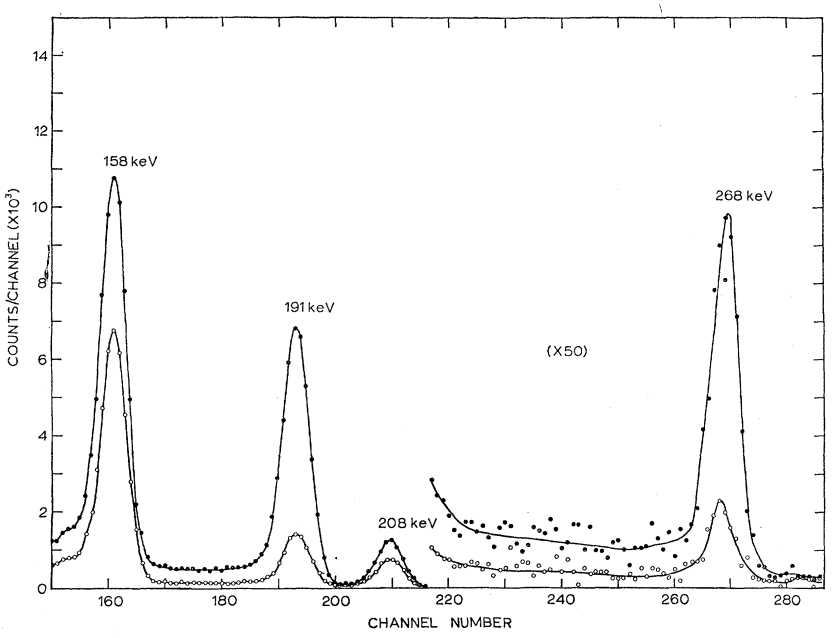

FIG. 4. Gamma-ray spectrum recorded with a lithium-drifted germanium semiconductor detector. This source was not purified by chemical removal of gold. The decay rate of the 158- and 208-keV peaks is that of Au^{199}. The lower spectrum (open circles) was taken 45 h after the upper spectrum (solid circles).

state ($J=2+$) of the even-even core of Pt^{196}. However, the presence of an $E0$ component in the 191-keV transition demands that the 268-keV state have spin and parity $\frac{1}{2}+$ rather than $\frac{3}{2}+$, in disagreement with the model. If the 268-keV level is indeed characterized by $\frac{1}{2}+$, no $E2$ component is present in the 191-keV transition.

It can be shown that

$$N_e(E0)/N_\gamma(M1)=\alpha_K(191)-\beta_1(191), \qquad (1)$$

where $\alpha_K(191)$ is in this case 1.59 ± 0.07, and $\beta_1(191)$ is 0.91, the mean of the two previously quoted theoretically calculated values of the conversion coefficient of an $M1$ transition of energy 191 keV. The data yield, for $N_e(E0)/N_\gamma(M1)$, a value of 0.68 ± 0.07. Since $N_e(M1)$ is $0.91N_\gamma(M1)$, $N_e(E0)/[N_e(E0)+N_e(M1)]$ becomes 0.43 ± 0.05. The fraction of the 191-keV transition proceeding by the $E0$ mode is calculated to be

$$N_e(E0)/[N_e(E0)+N_e(M1)+N_\gamma(M1)] =0.26\pm0.02. \qquad (2)$$

The transition probability of the $E(0)$ transition is given by

$$T_e(E0)=T_\gamma(M1)(\alpha_K-\beta_1)=W, \qquad (3)$$

where[17]

$$W=\Omega\rho^2, \qquad (4)$$

ρ being the strength parameter. Taking $T_\gamma(M1)$ to be 1.96×10^{11} sec^{-1}, ρ is calculated to be 0.66 ± 0.05. This value is to be compared with $\rho\sim\frac{1}{2}$ computed by Peker and Sliv,[15] taking $\alpha_K=2.5$, a calculation which could not be verified.

OTHER TRANSITIONS

Gamma rays at 155 and 202 keV have been reported recently in the decay of the isomers of Pt^{197}. The present studies indicate these quanta to arise from the presence of contaminating Au^{199} formed in the reactions $Pt^{198}(n,\gamma)Pt^{199}(\beta^-)Au^{199}$. These gamma rays, emitted in deexcitation of Hg^{199}, are shown in the spectrum of Fig. 4, where the calibration indicated quantum energies of 158 and 208 keV. From the figure, it is clear that the full-energy peaks of these two gamma rays decay with the 3.15-day half-life of Au^{199}, whereas the 191- and 268-keV peaks decay with the 18-h half-life of Pt^{197}.

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