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THE YIELD RATIO OF THE ISOMERIC PAIR $^{197m,197}\text{Hg}$ FORMED BY $^{197}\text{Au}(d,2n)^{197}\text{Hg}$ REACTION

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Abstract—The yield ratio of the isomeric pair formed by the reaction $^{197}\text{Au}(d,2n)$ was measured at different deuteron energies between 9 and 26 MeV. The results are briefly discussed.

STUDIES of the yield ratios of isomeric pairs produced in nuclear reactions are of interest in determining the mechanism of formation of these isomers.

It was observed experimentally^(1,2) that in different nuclear reactions where the same isomeric pair is produced, there is a variation in the ratio for the same excitation energy.

It was considered of some interest to study the yield ratio of the isomeric states ^{197m}Hg (spin $\frac{3}{2}^+$) and ^{197}Hg (spin $\frac{1}{2}^-$) in the nuclear reaction $^{197}\text{Au}(d,2n)^{197}\text{Hg}$. Experiments were performed irradiating gold with deuterons of energies ranging from 9 to 26 MeV.

EXPERIMENTAL

The yield ratio of the isomeric pair $^{197m}\text{Hg}/^{197}\text{Hg}$ in the reaction $\text{Au}(d,2n)$ was measured varying the deuteron energies between 9 and 26 MeV.

The yields of the isomeric pair were obtained using the stacked foil technique with 25 mg/cm² thick gold foils, which allowed simultaneous bombardment over a wide range of energies. The individual excitation functions of the isomers could not be determined absolutely owing to the flux variation across the gold foils.

The irradiations were performed using the internal beam of a 180 cm diameter synchrocyclotron in the orbit corresponding to 28.1 MeV energy. The variation of the radius of curvature inside the cyclotron over the width of absorber traversed by the particles was insignificant. The maximum dispersion of the beam was estimated to be 1.2 MeV at 28.1 MeV energy.

The deuteron energy in each foil of the stack was calculated from the range-energy curves of AARON *et al.*⁽³⁾

Separation methods

The irradiated foils were washed with dilute HCl and amalgamated with a small quantity of mercury. The mercury was separated from the gold by vacuum distillation at an elevated temperature. In this way the radioactive mercury was distilled with the carrier, and collected on inactive gold foils for later measurements.^(4,5)

Measurements method

Figure 1 shows the disintegration scheme of the isomeric pair under consideration.⁽⁶⁾

⁽¹⁾ R. A. SHARP and A. C. PAPPAS, *J. Inorg. Nucl. Chem.* **10**, 173 (1959).

⁽²⁾ K. I. ZHEREBTSOVA, T. P. MAKAROVA, Y. A. NEMILOV and B. L. FUNSTEIN, *Zh. Eksptl. Teoret. Fiz.* **35**, 1355 (1958).

⁽³⁾ W. A. AARON, B. G. HOFFMAN and F. C. WILLIAMS, U.S.A.E.C. Report (UCRL 663 (1951).

⁽⁴⁾ H. FRAUENFELDER, M. WALTER and W. ZUNTI, *Phys. Rev.* **77**, 557 (1950).

⁽⁵⁾ D. L. HUFFORD and B. F. SCOTT, *Radio Chemical Studies: The Fission Products* (Edited by C. D. CORYELL and N. SUGARMON) NNES, Plutonium Project Record, Div. IV, Vol. 14B Paper 16, p. 1. McGraw-Hill, New York (1951).

⁽⁶⁾ D. STROMINGER, J. M. HOLLANDER and G. T. SEABORG, *Revs. Modern Phys.* **30**, 777 (1958).

The relative yields of the isomers of 24 and 65 hr can be determined measuring the relative intensities of the 279 and 192 KeV γ -rays. Counting was performed with a single channel scintillation spectrometer⁽⁷⁾ using a NaI(Tl) 1×1 in. crystal and an E.M.I. 6262 B. photomultiplier tube. To

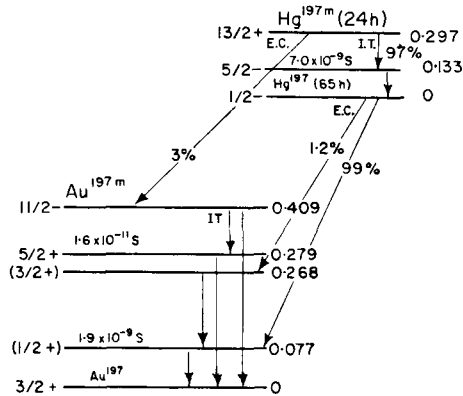


FIG. 1.— $^{197m,197}\text{Hg}$ disintegration scheme.

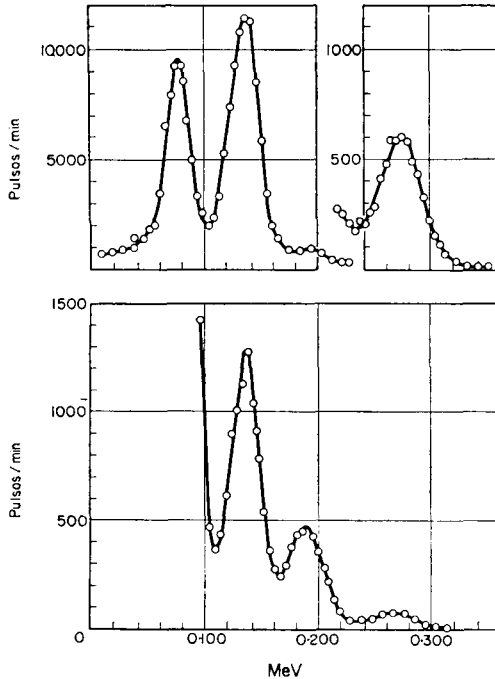


FIG. 2.— $^{197m,197}\text{Hg}$ γ -spectrum at different times from the end of irradiation.

avoid pile-up effects a tin foil of 0.581 g/cm^2 and another of molybdenum of 0.153 g/cm^2 were used as absorbers and the same geometry was used in all the measurements.

Figure 2 shows as an example the ^{197}Hg spectra corresponding to $17.2 \pm 0.2 \text{ MeV}$ deuteron energy, at different times after the end of irradiation.

The areas under the 279 and 192 keV photopeaks were obtained by graphical integration. The usual counting corrections were made and the disintegration scheme was taken into account when

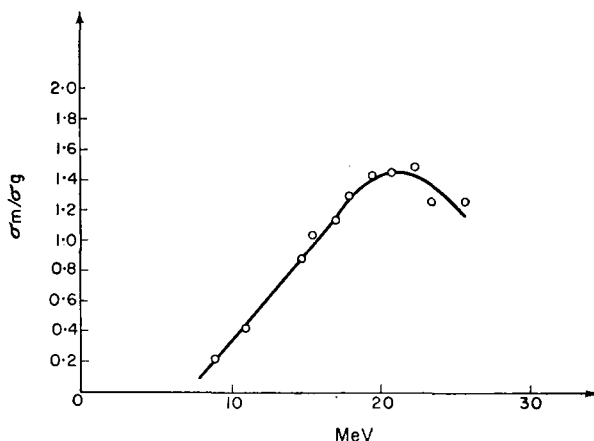
⁽⁷⁾ K. FRANZ and S. F. PINASCO. *Publicaciones C.N.E.A. Serie Fisica*. Vol. 1, No. 13 (1957) Rep. Argentina.

calculating the photopeak at each deuteron energy. At irradiation energies greater than 18 MeV, ^{195}Hg is produced by $^{197}\text{Au}(d,4n)$ reaction. The subtraction of this nuclide introduces some errors in the determination of the photopeak areas.* The values of the ratio σ_m/σ_g at the different deuteron energies used are given in Table 1. The energy values shown are the average between the incident and the emergent deuteron energies.

Figure 3 shows the ratio σ_m/σ_g plotted against the energy of the incident particles.

TABLE 1.

Energy (MeV)	σ_m/σ_g
8.8 ± 0.5	0.21
11.1 ± 0.3	0.42
14.7 ± 0.3	1.15
17.9 ± 0.2	1.30
20.8 ± 0.3	1.45
23.5 ± 0.2	1.25
25.9 ± 0.2	1.25

FIG. 3.—Yield ratio of ^{95}Nb isomers as a function of deuteron energy.

DISCUSSION

Several factors influence the yield ratio of the isomeric pairs in nuclear reactions and they have been discussed by different authors.^(4,9,10)

With simple bombarding particles a detailed study of these effects leads to some theoretical predictions of the reaction mechanism producing the isomeric states. With deuteron irradiation complications arise, since in this case, different processes such as total absorption of the deuteron or stripping can take place. This fact makes all theoretical considerations difficult. Generally in nuclear reactions at 30 MeV or lower energy only the "compound nucleus" formation is considered. In this case at low excitation energies, the formation of the isomer with spin similar to that of the target nucleus would be favoured. An increase in the excitation energy introduces

* Above 22 MeV these errors could be roughly estimated at about ± 15 per cent.

⁽⁸⁾ J. K. MEADOWS, R. M. DIAMOND and R. A. SHARP *Phys. Rev.* **102**, 190 (1956).

⁽⁹⁾ B. LINDER and R. A. JAMES, *Phys. Rev.* **114**, 322 (1959).

⁽¹⁰⁾ S. M. BAILEY. U.S.A.E.C. Report UCRL, 8710 (1959).

other factors that would lead to an increase in the yield of the initially unfavourable isomeric state.

An examination of Fig. 3 shows that at low energies, the formation of ^{197}Hg with a spin of $\frac{1}{2}-$ is favoured. This isomer has a spin closer to that of the target nucleus, ^{197}Au , whose fundamental state is $\frac{3}{2}+$. The proportion of the isomer with spin $\frac{1}{2}+$, increases with increasing deuteron energy.

Therefore, it can be concluded that the function relating the yield ratio of the isomeric states with energy shows the general trend observed in other reactions.^(2,8,9) The upper limit of available energies (28.1 MeV) and the increasing experimental errors (above 23 MeV the formation of ^{195}Hg increases), do not permit us to state whether the curve tends to a limiting value or whether it reaches a maximum at 20–22 MeV and then decreases.

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