PHOTOPROTONS FROM TANTALUM*

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Photoproton emission from tantalum has been studied by measuring the yield of the 5·5 hr isomer of ^{180}Hf produced in the ^{181}Ta(γ,p)$^{180\mathrm{m}}$Hf reaction. The experimental arrangements were similar to those used in a previous investigation (Carver and Turchinetz 1958) of the photodisintegration of tantalum, except that the shielding of the scintillation counter, a $1\frac{1}{2}$ in. diameter by 2 in. long NaI(Tl) crystal, has now been improved along the lines described by Pringle,

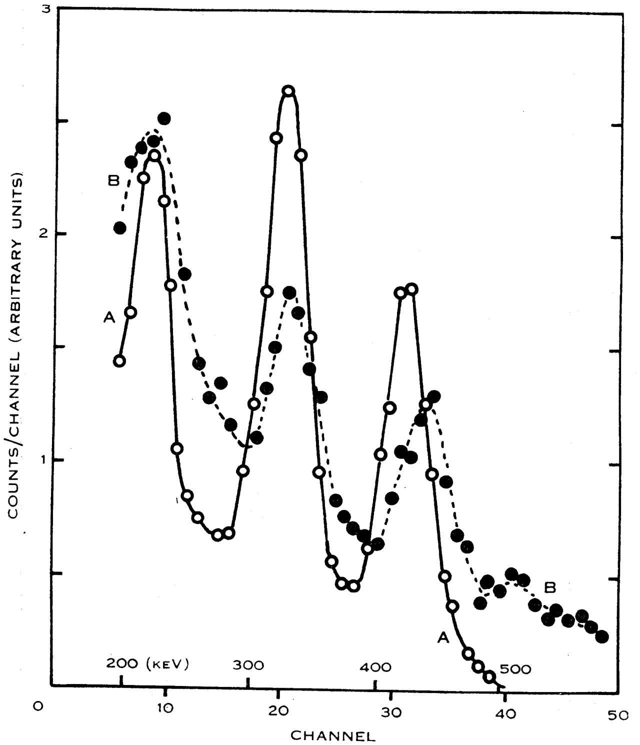

Fig. 1.—γ-Ray spectra of 5·5 hr ^{180}Hf and 2·1 hr ^{178}Ta. Spectrum B was measured 20 hr after spectrum A and corresponds mainly to ^{180}Hf.

Turchinetz, and Funt (1955). Larger quantities of tantalum (65 g) were used in the present experiments and, with these improvements, it was possible to separate the 5·5 hr ^{180}Hf activity from the similar, and more abundant, 2·1 hr ^{178}Ta activity produced in the ^{181}Ta(γ,3n)^{178}Ta reaction.

In the energy region from 200 to 500 kV ^{180}Hf has γ-ray lines at 216, 332, 443, and 501 keV, and ^{178}Ta has lines at 214, 326, 332, and 427 keV (Strominger,

* Manuscript received May 23, 1960.

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Hollander, and Seaborg 1958). At lower energies the γ-ray spectrum is dominated by 8·15 hr ^{180}Ta produced in the ^{181}Ta(γ,n)^{180}Ta reaction. The difference between the γ-ray spectra of ^{180}Hf and ^{178}Ta is illustrated in Figure 1, which shows two of the observed spectra. Spectrum B of Figure 1 was measured 20 hr after spectrum A and corresponds mainly to ^{180}Hf. An analysis of the decay of these γ-ray lines, an example of which is shown in Figure 2, indicates that there are two components with half-lives of 5·5 and 2·1 hr, corresponding to ^{180}Hf

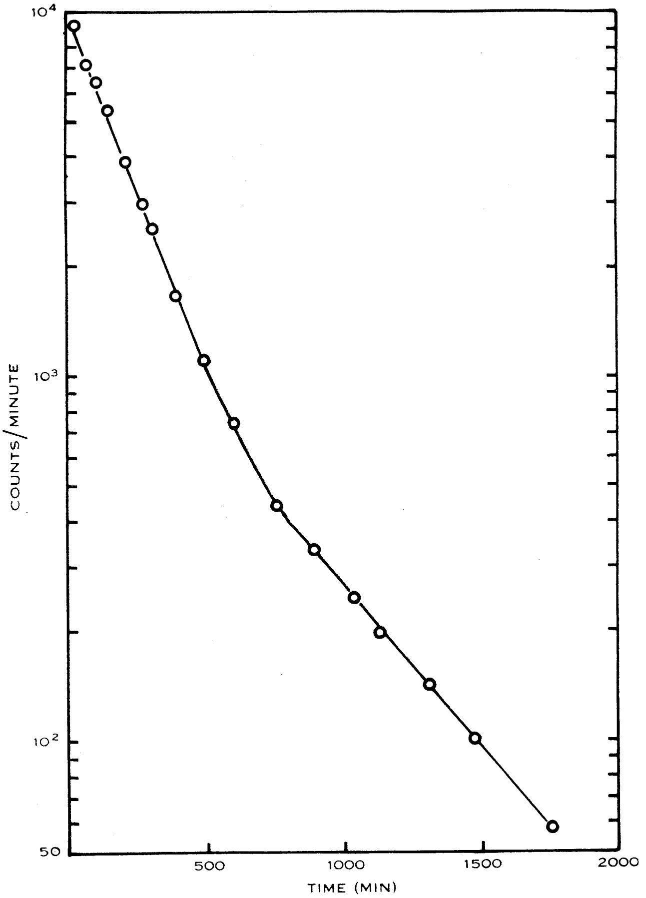

Fig. 2.—Decay curve for the 5·5 hr ^{180}Hf and 2·1 hr ^{178}Ta γ-rays of Figure 1.

and ^{178}Ta respectively. It is interesting to note that the half-life of ^{178}Ta obtained in this way is the same as that measured by Wilkinson (1950), whereas if no correction is made for the 5·5 hr component a value of 2·5 hr is obtained (Carver and Turchinetz 1958). In this analysis a small correction has been made for the bremsstrahlung produced by the β-particles of 8·15 hr ^{180}Ta which is produced in the ^{181}Ta(γ,n) reaction. This correction was made by irradiating a tantalum sample at 15 MeV, where there is no yield of ^{178}Ta or ^{180}Hf, and normalizing the bremsstrahlung tail to the intensity of the 55 keV X-ray peak.

The measured yield function and the derived cross-section curve for the $^{181}Ta(\gamma,p)^{180m}Hf$ reaction are shown in Figure 3. The points on the yield function were obtained from a least squares analysis of the 5·5 hr ^{180}Hf plus 2·1 hr ^{178}Ta γ-rays. The absolute cross-section scale was derived by comparison of these yields with the 10 min ^{62}Cu activity induced in copper foils using the absolute $^{63}Cu(\gamma,n)$ cross-section data of Berman and Brown (1954). This method is similar to that previously used to determine the (γ,n), $(\gamma,2n)$, and $(\gamma,3n)$ cross sections in ^{181}Ta (Carver and Turchinetz 1958).

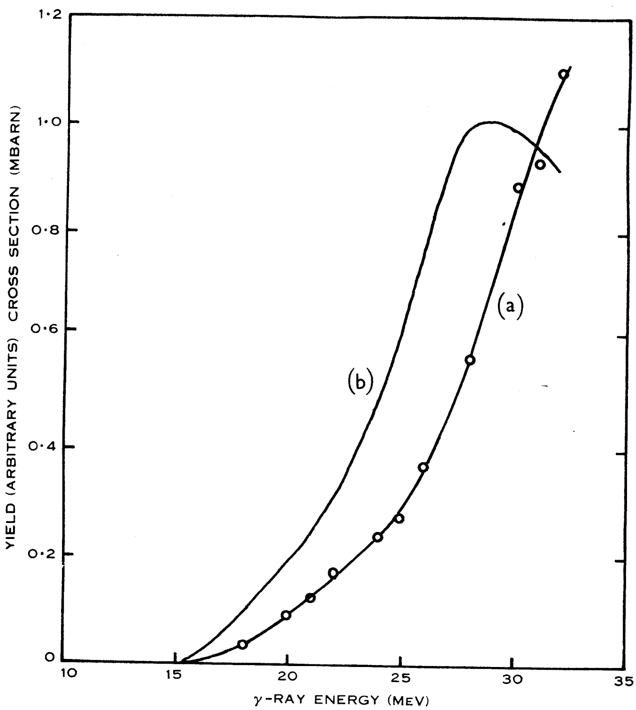

Fig. 3.—(*a*) The yield curve and (*b*) the derived cross section for the $^{181}Ta(\gamma,p)^{180m}Hf$ reaction.

The threshold for the $^{181}Ta(\gamma,p)$ reaction is 6·7 MeV (Wapstra 1958), but owing to the effect of the Coulomb barrier there is no appreciable yield below a γ-ray energy of $\sim$16 MeV. The $^{181}Ta(\gamma,p)$ reaction leading to the 5·5 hr isomer of ^{180}Hf has a peak cross section of 1·0 mbn at a γ-ray energy of 28 MeV and an integrated cross section to 32 MeV of (10 ± 2) MeV mbn* which corresponds to 0·3 per cent. of the total integrated γ-ray absorption cross section. Owing to the difference between the shapes of the (γ,p) and the total γ-ray cross section the yield for the (γ,p) reaction leading to the isomeric state is 0·1 per cent. of the total yield for all γ-ray processes. Most of the previous data about (γ,p) cross

* Approximately equal contributions to the error come from the analysis of the decay curves and from the comparison of the ^{180}Hf plus ^{178}Ta yields with the ^{62}Cu yield. There is a smaller error, 6 per cent., in Berman and Brown's (1954) estimate of the integrated $^{63}Cu(\gamma,n)$ cross section on which the present determination is based.

sections in the heavy nuclei have been obtained with 23 MeV bremsstrahlung (e.g. Toms and Stephens 1955). The present results, together with those obtained for caesium and iodine by Taylor (1960) in this laboratory, indicate that higher energy γ-rays make a considerable contribution to the photoproton emission.

Toms and Stephens (1955) used photographic plates to measure the total photoproton yield from tantalum for 23 MeV bremsstrahlung. Combining their result with the present measurements suggests that at 23 MeV the 5·5 hr isomeric state is populated in $\sim$10 per cent. of the (γ,p) disintegrations. The spin of the 5·5 hr level of ^{180}Hf is probably 9 and the ground states of ^{180}Hf and ^{181}Ta have spins 0 and 7/2 respectively (Strominger, Hollander, and Seaborg 1958), so that the present results are consistent with the general rule that in the production of an isomeric pair the member with spin closest to that of the target nucleus is favoured. If the bulk of the (γ,p) reactions proceeds through direct transitions leading to states in ^{180}Hf of only moderate excitation it is not surprising that the magnitude of the preference for the low spin state is larger than in the ^{181}Ta$(\gamma,3n)^{178}$Ta, ^{178m}Ta reactions, where the high spin state is populated in 30 per cent. of the disintegrations (Carver and Turchinetz 1958).

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