considered to be fairly well bracketed, as is most clearly shown by Fig. 5 for the total cross sections. Certainly, greater accuracy in the experimental quantities used in numerically fixing these cross sections will be almost a prerequisite before refined photodisintegration measurements can distinguish the presence of such effects as are due to tensor forces, exchange forces, exchange currents, or particular well shape. However, as a standard to be used for determining other photo-process cross sections the present calculations indicate that such a calculated result as σ_{II}, as our best approximation to the correct total cross section, can only be considered to be accurate to within 15 percent. About 5 percent of this arises from uncertainties in the values of empirically determined parameters (effective ranges, etc.), while the remainder arises from the uncertainties introduced by lack of knowledge concerning the potential interaction, noncentral interactions, and exchange moments.

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New Neutron-Deficient Isotope of Silver*

B. C. HALDAR† AND EDWIN O. WIIG
Department of Chemistry, University of Rochester, Rochester, New York

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Silver-103 of 1.1-hour half-life, produced by bombarding silver with high-energy protons, was identified by following the decay with β-proportional, scintillation, and x-ray proportional counters and by milking the daughter, 17-day Pd^{103}, through seven half-lives. Measurements with a β-ray survey spectrometer showed the presence of conversion electrons of 0.6-Mev energy and positrons of 1.3-Mev maximum energy, both of which decayed with a half-life of 1.1 hours. Aluminum absorption measurements also gave 1.3 Mev as the maximum β^+ energy. Ag^{103} decays in part by K capture.

THE existence of previously unknown Ag^{103} of 1.1-hour half-life was investigated by bombarding silver with protons of energy 80, 100, and 170 Mev in the internal beam of the 130-inch synchrocyclotron of the University of Rochester. Bendel *et al.*[1] have reported bombardment of Pd foil with 12-Mev deuterons and examination of the activity associated with the silver fraction. They observed that conversion lines of 530- and 740-kev associated with the silver activity decayed with half-lives of 1.1 hours, which they could not assign to any known silver isotope. In view of the present results it seems quite likely that they synthesized 1.1-hour Ag^{103} from Pd^{102} by a (d,n) reaction.

EXPERIMENTAL

Silver powder, determined by spectrochemical analysis to contain only traces of copper and possible traces of lead, was wrapped in a 5-mil aluminum foil envelope and bombarded, usually for one hour.

The bombarded sample was dissolved in hot nitric acid containing ions of In, Cd, Pd, Y, Sr, and Rb as carriers. The resulting solution was diluted with water and AgCl precipitated by addition of HCl. The washed solid was dissolved in NH_4OH and the solution scavenged twice with $Fe(OH)_3$. Addition of H_2S to the solution gave a precipitate of Ag_2S, which was washed and dissolved in hot concentrated HNO_3. Dilution and addition of HCl resulted in precipitation of AgCl, which was dissolved in NH_4OH and the $Fe(OH)_3$, Ag_2S, AgCl purification cycle repeated. The final AgCl precipitate was washed with water, alcohol and ether and suitably mounted for counting with β-proportional, scintillation, and x-ray proportional counters. Samples were also prepared for β-ray spectrometer and aluminum absorption measurements.

In milking experiments a known amount of $Pd(NO_3)_2$ as carrier in solution was added to a known weight of purified active AgCl. The mixture was allowed to stand for 45 minutes and then dissolved in NH_4OH solution. At the end of 1.1 hours from the previous precipitation of AgCl, the NH_4OH solution was made acid with HCl and AgCl reprecipitated and separated. The supernatant was scavenged with AgCl, after which palladium dimethylglyoxime was precipitated, separated, and washed. A solution of the precipitate in hot concentrated HNO_3 was again scavenged with AgCl. After dilution of the supernatant, palladium was separated as palladium dimethylglyoxime, washed, dried, mounted, and weighed. The

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† Postdoctoral Research Associate in Chemistry.
[1] Bendel, Shore, Brown, and Becker, Phys. Rev. **90**, 888 (1953).

K-capture decay of 17-day Pd^{103} was followed with an x-ray proportional counter.

RESULTS

Half-Life and Mass Number

The decay curve for the silver activity produced by bombardment with 100-Mev protons and followed with a β-proportional counter is illustrated in Fig. 1. Similar curves were obtained with a scintillation counter and for all three proton energies. Besides long-lived activity, the silver sample was found to decay with half-lives of 1.1 hours and 25 minutes. The latter activity presumably indicates the presence of the known isotopes[2] Ag^{106} (24 minutes) and/or Ag^{104} (27 minutes). Measurements with an x-ray proportional counter also showed the 1.1-hour activity along with other activities (Fig. 2, curve A). Silver activities of 16.3 minutes and 1.2 hours were originally assigned by Ens[3] to Ag^{104} and Ag^{102}, respectively. However, he expressed doubt concerning the assignment of the 1.2-hour activity, which was of low intensity. In the most recent "Table of Isotopes"[2] the 16-minute decay is assigned to Ag^{102} and the 1.2-hour to Ag^{104}. It would now appear that perhaps Ens' 1.2-hour Ag activity was actually 57-minute Rh^{103m}, which was unknown at the time. The latter has since been prepared by a

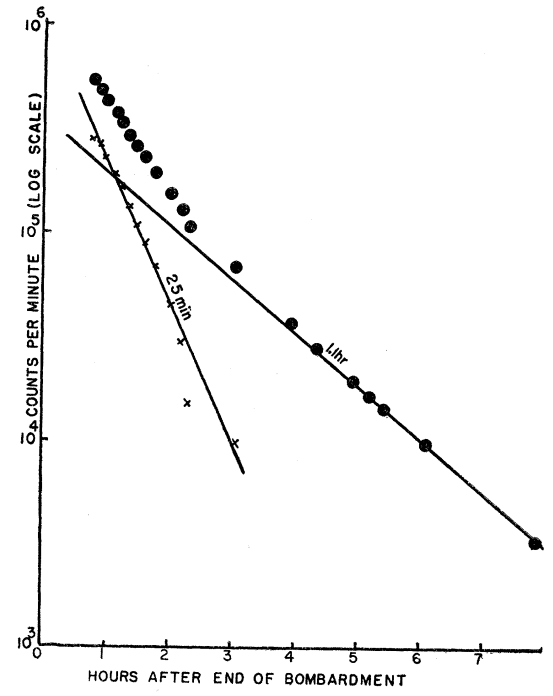

FIG. 1. Decay curve of active silver as observed with a beta-proportional counter.

[2] Hollander, Perlman, and Seaborg, Revs. Modern Phys. **25**, 469 (1953).
[3] T. Ens, Phys. Rev. **56**, 872 (1939).

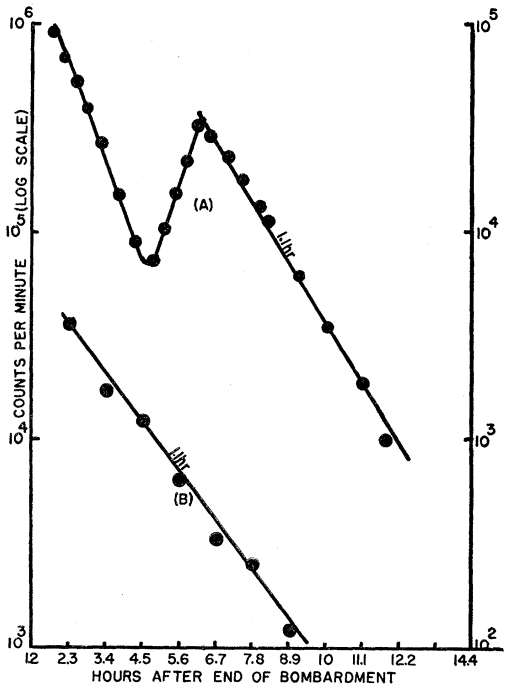

FIG. 2. (A) Decay of active silver as observed with an x-ray proportional counter. (B) Yields of Pd^{103} daughter extracted from chemically purified active silver.

(p,p) reaction[4] on Rh^{103}, and Rh was present in Ens' Pd target. No data have as yet appeared for the more recently reported[2] 1.2-hour Ag activity. At any rate, in view of the relatively short half-life of Ag^{104} and of the energy available in the transition from the ground state of Ag^{102} to that of Pd^{102} (5.3 Mev, calculated by the β-decay systematics of Coryell[5]), Ag^{102} should have a short half-life. This suggested that our observed 1.1-hour Ag activity was due to Ag^{103}, a conclusion which was confirmed by extraction of the known 17-day Pd^{103} daughter.

The results of the Pd milking experiments are summarized in Fig. 2, curve B. The yield of Pd activity decreases with a 1.1-hour half-life. The separated Pd decayed by K capture and with a 17-day half-life.

Mode of Decay and Radiation Characteristics

Measurements made with a β-ray survey spectrometer indicated that the 1.1-hour Ag activity emits positrons of 1.3-Mev maximum energy. At the magnet current corresponding to 0.52 Mev, the peak of the 1.3-Mev β^+ emission, the activity was found to decay with a 1.1-hour half-life. Aluminum absorption data (Fig. 3) also gave 1.3 Mev as the maximum positron energy. The 0.4-Mev β^- rays of 24-minute Ag^{106} were also seen but were allowed to decay out before starting measurements on Ag^{103}. The high count remaining in

[4] N. Hole, Arkiv. Mat. Astron. Fysik **36A**, No. 2 (1948).
[5] C. D. Coryell, Ann. Rev. Nuclear Sci. **2**, 305 (1953).

Fig. 3 is due to γ rays from 8.3-day Ag^{106} and 40-day Ag^{105}, and to a soft component equivalent to betas of ~0.75-Mev maximum energy. The latter was not observable until 2 days after the bombardment and was possibly due to some other silver iostope or to the presence of impurity activity.

A calculation by Coryell's β-decay systematics[5] gives 1.72 Mev as the total disintegration energy of Ag^{103} in the positron ground state transition. This would suggest that Ag^{103} decays by emission of 1.3-Mev β^+ to an excited state of Pd^{103}, which then decays to the ground state by gamma emission. Conversion electrons of 0.6-Mev energy observed in the β-ray spectrometer data were found to decay with a half-life of 1.1 hours. Thus the observed total energy, 1.92 Mev,

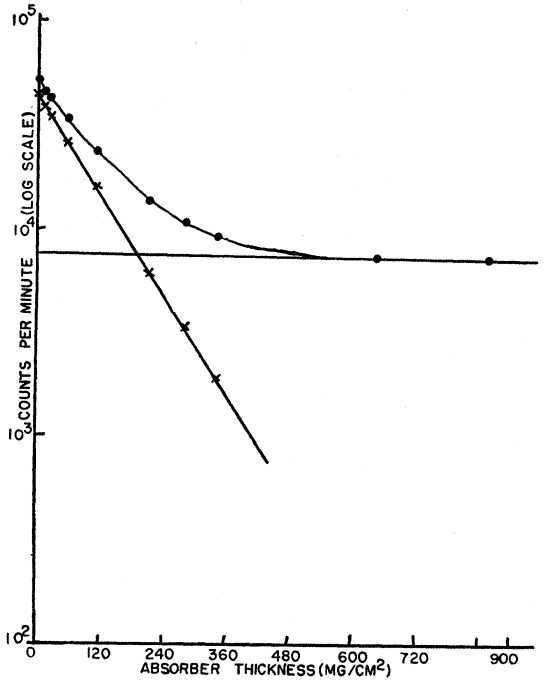

FIG. 3. Aluminum absorption curve of active silver 7 hours after end of bombardment.

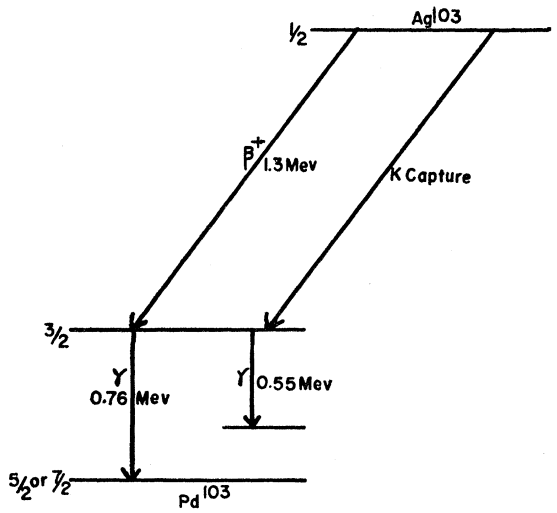

FIG. 4. Suggested decay scheme for silver-103.

is within the limits of error in agreement with the estimated energy.

By way of summary, the experiments reported here show 1.1-hour Ag^{103} to decay by emission of 1.3-Mev β^+, ~0.6-Mev γ rays and K capture.

By combining our data and the 530- and 740-kev conversion lines of Bendel *et al.*,[1] which our results show are associated with Ag^{103}, the tentative decay scheme shown in Fig. 4 may be suggested for Ag^{103}. The value of log ft is ~4.8, as calculated from Feenberg and Trigg.[6] From the shell model the spin of Ag^{103} in the ground state is expected to be $\frac{1}{2}$ due to the 47th proton in the $p_{\frac{1}{2}}$ state. The spin of the ground state of Pd^{103} is due to its 57th neutron which may occupy the $d_{\frac{5}{2}}$ or $g_{7/2}$ state.

We wish to express our thanks to Professor S. W. Barnes, Mr. W. Coombs, and the members of the operating crew of the Rochester 130-inch synchro-cyclotron for their assistance with the bombardments.

[6] E. Feenberg and G. Trigg, Revs. Modern Phys. **22**, 401 (1950).