Negative-Pion Activation of Silver*†

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The yields of some isotopes of palladium, rhodium, and ruthenium produced by the reaction of π^- mesons with silver were determined radiochemically. These results, together with those from a similar study with bromine, make possible a comparison with the data obtained with photographic plates. The results are consistent with each other within the uncertainties of the experimental data.

A STUDY has been made of the reaction with silver of negative pions produced at the University of Chicago synchrocyclotron. The irradiation arrangement was much the same as in the bromine experiments of Sugihara and Libby.[1] 2 to 4 kg of powdered silver were irradiated with a collimated 5 cm^2 beam of 122-Mev negative pions. The targets were thicker than the pion range. The irradiations were conducted for 7 to 12 hours at intensities of about 5000 mesons per second. The irradiated silver was dissolved in concentrated nitric acid in the presence of palladium, rhodium, and ruthenium carriers. The carriers were chemically recovered from the silver nitrate solution and the decay of the activities in the respective fractions was followed on Geiger counters. The product isotopes were identified by their half-lives. Counting efficiencies of product isotopes which decayed primarily by the K-capture process were estimated by producing these same isotopes by the proton irradiation of silver nitrate and counting their K x-rays with Geiger counters filled with mixtures of krypton, helium, and butane.

The results are presented in Table I. The percent yields signify the fraction of the incident mesons which produced the nuclide in question. The total yield for all rhodium isotopes was estimated from a plot of yield *versus* mass number. The yield curve was taken to be smooth and symmetric about a line parallel to the yield axis. The yields for the other elements were determined by fitting the rhodium yield curve to the yield data for palladium and for ruthenium. The yield of Pd^{101} appeared to be too high. Assignment of part of the observed ~9-hr palladium activity to 13-hr Pd^{109} instead of all to 9-hr Pd^{101} would explain not only the apparently high yield of Pd^{101} but also the low yield of Rh^{101}. Pd^{109} could have been produced from Ag^{109} by a (π^-,π^0) reaction, a (μ^-,ν) reaction with the μ^- meson contamination in the pion beam, or an (n,p) reaction with the secondary neutrons resulting from the pion reactions. The yield data indicate that five or six neutrons are emitted with the highest probability in the pion reactions with silver which involve the ejection of zero, one, or two protons. This is in reasonable agreement with results of previous radiochemical work.[1–3]

TABLE I. Yields from negative pions on silver.

Isotope	Yield (%)
Pd^{103}	4.9±0.8
Pd^{101}	6.8±0.6
Pd^{100}	1.9±0.3
Rh^{105}	0.9±0.1
Rh^{102}	3.8±0.4
Rh^{101}	−0.2±1.2
Rh^{100}	1.8±0.3
Ru^{103}	1.1±0.2
Ru^{97}	0.8±0.2

From the yield curves, the total elemental yields were estimated to be 22% for palladium, 16% for rhodium, and 22% for ruthenium. Considering the rather large uncertainties in the results of the present work, the averages of the yields of corresponding reactions of the mesons with silver and bromine cannot be said to be in disagreement with the prong distribution of the heavy-element stars deduced by Menon *et al.*[4] from photographic plate studies. The results are also in rough agreement with the mean numbers of neutrons, protons, and α-particles deduced by Puppi *et al.*,[5] from Monte Carlo calculations. They made these theoretical calculations on the absorption of π^- mesons at rest by hypothetical nuclei with $Z=43$ and $A=100$.

Studies of spallation reactions of projectiles in the hundred-Mev range with medium weight nuclei have shown that the products which are displaced from the target nucleus by a few units of Z account for a large fraction of the total yield and tend to be neutron-deficient. The yields of the products of the reaction of π^- mesons with medium-weight nuclei behave in a similar fashion. This supports the belief that the events that follow absorption of a pion by a nucleus are similar to those in spallation; namely (a) escape from the nucleus of fast nucleons, some of which were formed from knockon processes, and (b) the stabilization of the excited residual nucleus by the evaporation mechanism.

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