Title
BROMINE ISOTOPES PRODUCED BY CARBON ION BOMBARDMENT OF COPPER

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In addition to providing a novel means for the synthesis of transplutonium elements,[1] the accelerated carbon ion beam of the Berkeley 60-inch cyclotron may also be used conveniently for the study of neutron deficient nuclides, for it is a property of carbon ion induced transmutations in any but the lightest elements that the ratio of protons to neutrons added to the target nucleus is virtually always larger than unity.

The 60-inch cyclotron, which accelerates He^4 (+2) ions to ~40 Mev, should in theory produce C^{12} (+6) ions of ~120 Mev. However, unpublished experiments with G. B. Rossi and A. Ghiorso[2] have shown that the energy spread of the internal carbon ion beam is wide, a most probable energy being perhaps nearer to 90 than to 120 Mev. Beam currents measured through 1.5 mils of tantalum absorber, corresponding to the passage of ions with kinetic energies exceeding ~80 Mev, have averaged between 0.01 and 0.1 μA.

Copper foils have been bombarded in the carbon beam, and bromine chemical fractions subsequently isolated. Their decay curves showed two activities, with half-lives of 95 ± 3 minutes and 36 ± 2 minutes, as shown in Fig. 1. The first of these is to be identified with the 1.7 hour bromine isotope discovered by

Woodward, McCown, and Pool,[3] and assigned by them to Br^{75}, on the basis of proton and deuteron bombardments of enriched Se^{74}. In the present experiments, the reaction producing this isotope would be Cu^{65} (C, 2n) Br^{75}. The 36 minute activity has not been reported previously.

The 16 hour positron emitter Br^{76} has not been observed in any carbon ion bombardments of copper. From the gross activity curves, which decay to background without tailing out into a longer component, a lower limit of ~30 can be set on the ratio of the $Cu^{65}(C, 2n)Br^{75}$ to the $Cu^{65}(C, n)Br^{76}$ reaction.

In an attempt to fix the isotopic assignment of the 36 minute bromine relative to 95 minute Br^{75}, carbon ion bombardments of isotopically enriched CuO targets[4] were made. The CuO samples carried the following analyses:

CuO I	Cu^{63}	99.7 ± 0.3%	Cu^{65}	0.3%
CuO II	Cu^{63}	1.84 ± 0.02%	Cu^{65}	98.16 ± 0.02%.

Br^{75} can be produced by carbon ions only from Cu^{65}, since a $Cu^{63}(C, \gamma)Br^{75}$ reaction would not be likely. Thus, from CuO I, any Br^{75} which is produced should have come only from the ~0.3% Cu^{65} remaining in that sample. One would then expect the ratio Br^{75}(from CuO II)/Br^{75}(from CuO I) to be ~ 300. Actually observed in two bombardments were ratios of 50 and 100, which, considering the experimental uncertainties in carbon ion beam current and chemical yields, are not inconsistent with the isotopic enrichment reported.

The cross sections for the $Cu^{65}(C, 2n)Br^{75}$ reaction and the $Cu^{65}(C, xn)$ 36 min $Br^{<75}$ reaction were roughly equal, indicating that the latter activity may be due to the $Cu^{65}(C, 3n)Br^{74}$ or $Cu^{65}(C, 4n)Br^{73}$ reaction. There was no appearance of the 7.1 hour Se^{73} in any of the bromine decay durves, so it is fairly certain that the 36 minute bromine does not decay through that state; but in view of the present uncertainty in the mode of decay of Se^{73}, one cannot on these grounds eliminate the possibility that the 36 minute bromine is Br^{73}. However, the following evidence points to its assignment to Br^{74}: in spite of over a fiftyfold enrichment of Cu^{63} in CuO I as compared with CuO II, the ratio of 36 minute/95 minute activities was only slightly enhanced in CuO I, and the absolute yield of the 36 minute activity was lower by a factor of about 50 in CuO I than in CuO II, indicating that the 36 minute activity has been made in Cu^{63} by a reaction with a very low cross section, and hence may be assigned tentatively to Br^{74}, by the $Cu^{63}(C, n)Br^{74}$ reaction.

In carbon ion bombardments of $Cu^{63}O$, but not in those of $Cu^{65}O$, a 4 ± 1 minute bromine activity has also been observed, but no further details are presently known about this activity.

I am greatly indebted to I. Perlman for his helpful comments, and to G. B. Rossi and the crew of the 60-inch cyclotron for their help in making these bombardments.

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[1] Ghiorso, Thompson, Street, Jr., and Seaborg, Phys. Rev. 81, 154 (1951).

[2] J. M. Hollander, University of California Radiation Laboratory Report UCRL-1395 (June 1951).

[3] Woodward, McCown, and Pool, Phys. Rev. 74, 870 (1948).

[4] These enriched samples were kindly loaned by the Stable Isotopes Division of the Oak Ridge National Laboratory.

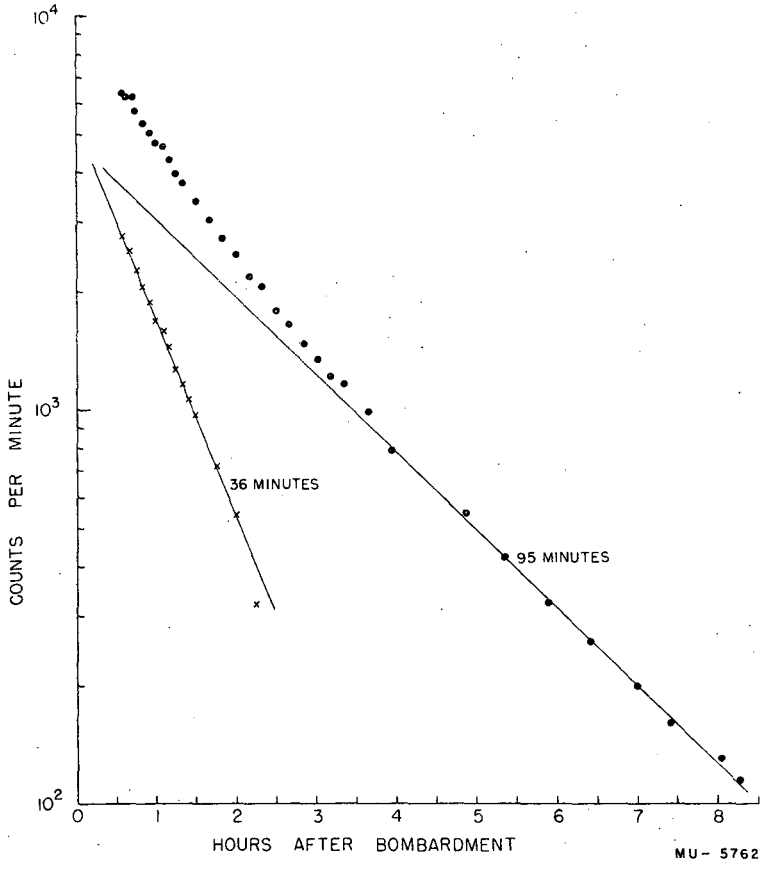

Fig. 1. Typical decay curve of bromine fraction from Cu + C^{12} bombardments.