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ACCELERATION OF STRIPPED C12 AND C13 NUCLEI IN THE CYCLOTRON

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UNIVERSITY OF CALIFORNIA  
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J. F. Miller, J. G. Hamilton,  
T. M. Putnam, H. R. Haymond and G. B. Rossi

August 25, 1950

Berkeley, California

-2-

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ACCELERATION OF STRIPPED  $C^{12}$  AND  $C^{13}$  NUCLEI IN THE CYCLOTRON

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August 25, 1950

The acceleration of stripped  $C^{12}$  and  $O^{16}$  nuclei in the cyclotron has been reported<sup>(1,2,3,4)</sup>. The significance of this feat was limited by the fact that the obtainable intensities were far too small to produce a sufficient number of nuclear reactions to permit the detection of radioisotopes formed by the transmutation of target nuclei by these heavy ions. The discovery of the transuranic elements has given considerable impetus to attempts to achieve this. For the past 4 years, a program to increase the intensities of accelerated heavy ions has been under way at the Crocker Laboratory using the 60" Cyclotron. This program has included attempts to accelerate  $B^{10}$ ,  $B^{11}$ ,  $C^{12}$ ,  $C^{13}$ ,  $N^{14}$ ,  $O^{16}$ ,  $O^{17}$ ,  $O^{18}$ , and  $F^{19}$ .

To date, detectable intensities of completely stripped  $C^{12}$  and  $C^{13}$  ions have been observed. A hooded capillary ion source gave the best results. The source gas for the production of carbon ions was  $CO_2$ . Range determinations using aluminum absorbers were made and the data is summarized in Table I, giving the measured and expected range-energy relationships.

The maximum intensity of the external deflected beam of  $C^{12}$  ions that has been obtained to date is of the order of  $10^5$   $C^{12}$  nuclei per second, and  $10^4$   $C^{13}$  nuclei. In the case of  $C^{13}$ , material enriched to 50 percent of this isotope was employed.

Aluminum and gold were selected as target elements as they can be obtained in a high degree of purity and possess a single stable isotope. The transmutation products sought were  $\text{Cl}^{34}$  and the light isotopes of astatine. These possess conveniently short half-lives and may be isolated by relatively simple chemical procedures. The At isotopes were particularly attractive in view of the fact that the lighter ones, notably  $\text{At}^{203}$ ,  $\text{At}^{204}$ , and  $\text{At}^{205}$  could not be produced in the 60" Cyclotron by the ever present contamination of alpha particles.

Internal targets of Al and Au were bombarded. The 33 minute positron emitting  $\text{Cl}^{34}$  and the 24 minute  $\text{At}^{205(5)}$ , were chemically isolated and identified by the character of their radiations and rates of radioactive decay. Further proof of identification was made of  $\text{At}^{205}$  by the use of the alpha particle pulse analyzer developed by Mr. Ghiorso who made these determinations for us. The yields were in the range of from .1 to .002 microcuries. Assuming the cross-section for the production of  $\text{Cl}^{34}$  from Al to be in the range of 0.1 barn, the internal  $\text{C}^{12}$  beam was estimated to be of the order of  $10^8$  ions per second. The nuclear reactions for the production of these two radioisotopes are presumably  $\text{Al}^{27}(\text{C}^{12}, \alpha n)\text{Cl}^{34}$ ,  $\text{Au}^{197}(\text{C}^{12}, 4n)\text{At}^{205}$ .

Internal target bombardment of Al with stripped  $\text{C}^{13}$  nuclei gave inconclusive results. The bombardment of Au with  $\text{C}^{13}$  ions produced a small amount of alpha particle activity. The presence of 11 and 25 minute components suggest the possibility that the 7 minute  $\text{At}^{203}$  and 24 minute  $\text{At}^{205}$  had been produced.



Control runs were made to rule out radioactive contamination. Al and Au were bombarded with alpha particles and runs were made using an argon arc at the magnetic resonance value for  $C^{12}$ . In both instances, no  $Cl^{34}$  from Al and no alpha activity in the gold was observed. Covering the targets with 0.3 mil Al foil demonstrated that sputtering of radioactive materials in the cyclotron could not account for the production of  $Cl^{34}$  or the alpha particle activity in the  $C^{12}$  and  $C^{13}$  bombarded Au.

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TABLE I. RANGES AND ENERGIES OF ACCELERATED NUCLEI OF  ${}^2\text{He}^4$ ,  ${}^6\text{C}^{12}$  AND  ${}^6\text{C}^{13}$ .

Particle	Measured Range (mg/cm <sup>2</sup> Al)	Expected Range	Measured Energy (Mev)	Expected Energy (Mev)
${}^2\text{He}^4$	$158 \pm 2$	158	$38.6 \pm 0.4$	38.6
${}^6\text{C}^{12}$	$53.5 \pm 2$	54	$115 \pm 2.4$	116
${}^6\text{C}^{13}$	$55.5 \pm 2$	58	$122 \pm 2.5$	125

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