3.16 Mev is not excluded by our work. This decay scheme is also in agreement with the results of $\beta-\gamma$ and $\gamma-\gamma$ coincidence measurements carried out by us with a Geiger counter arrangement described elsewhere.[5]

It should be pointed out that the total decay energy of 6.17 $\pm$0.05 Mev following from this decay scheme disagrees appreciably with the threshold of 5.1$\pm$0.02 Mev in the reaction $Ni^{60}(p,n)Cu^{60}$ found by Leith *et al.*[1] However, our value is more in line with the systematics of β-decay energies for the other Cu isotopes.[3]

A detailed discussion of these results will appear in *Physica*. The Cu^{60} was prepared by irradiation of metallic Ni with 26-Mev deuterons in the Philips synchro-cyclotron. The chemical separation was performed by Miss G. de Feyfer and Miss R. Boelhouwer of our Chemical Department. We thank Dr. C. J. Bakker and Dr. A. H. W. Aten, Jr., for their interest in this work and Mr. L. Th.M. Ornstein for assistance with the experiments.

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The Acceleration of Nitrogen-14 (+ 6) Ions in a 60-Inch Cyclotron*

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A STUDY of the acceleration of heavy ions in the 60-inch cyclotron at the University of California Crocker Laboratory has been in progress for some time. Although this effort has been only part of our over-all program, a continuous improvement in performance has taken place. The original results published by this group[1-5] have recently been augmented by other laboratories,[6-10] where the emphasis, in general, has been on attempts to accelerate ions other than $C^{12}(+6)$. Specific ions include $C^{13}(+6)$, $Ne^{20}(+9)$, $Be^{9}(+4)$, $N^{14}(+6)$, $C^{12}(+5)$, $C^{13}(+5)$, and $O^{16}(+6)$. Developmental work by the Crocker Laboratory group with ion sources, beam monitoring techniques, and other cyclotron parameters has yielded larger $C^{12}(+6)$ beams than previously reported. These larger beams have permitted further experimental work in the fields of biology and nuclear chemistry. Carbon-12 (+6) internal beam intensities of 0.2 microampere have been realized with energies greater than 100 Mev; externally deflected beams of 0.001 microampere with an energy of 120 Mev have been consistent.

The efforts of this group in the acceleration of ions have been rewarding in the cases of those ions with a lower-order ionization state that is a one-third multiple of the ion to be accelerated. In more general terms, a given cyclotron can accelerate any ion for which

$$e/m=K/(2n+1), \qquad (1)$$

where $n=0, 1, 2, \cdots$, and K is a design parameter, i.e, $K=g(\omega,H)$. In the cases where $n=0$, the fundamental ion frequency (ω_i) will prevail; where $n=1$, the ion frequency will be $1/3\omega_i$. This fact was reported earlier[11] and has since been corroborated by the University of Birmingham group[8,9] working with their 60-inch cyclotron.

The techniques used with $C^{12}(+6)$ ion acceleration have been applied to $N^{14}(+6)$ ions by changing the ion source gas from CO_2 to N_2, and increasing the magnetic field to resonance for $K=6/14$, in Eq. (1). This provides that for $n=0$, $N^{14}(+6)$ is accelerated at the fundamental ion frequency (ω_i); $n=1$ indicates an $e/m=2/14$ which allows for acceleration of $N^{14}(+2)$ at $1/3\omega_1$. Under these conditions internal beams of $N^{14}(+2)$ have been measured to a level of 50 microamperes while those of $N^{14}(+6)$ are of the order of 0.1 microampere with energies greater than 100 Mev. This again suggests a mechanism for production of $N^{14}(+6)$ by secondary stripping; namely, that $N^{14}(+2)$ ions produced in the ion source are accelerated at $1/3\omega_i$ and are further ionized to $N^{14}(+6)$ in the region of the ion source. It is not certain whether the further ionization to the $N^{14}(+6)$ state is due either to collisions of the $N^{14}(+2)$ ions with gas molecules within the vacuum system or due to bombardment of the $N^{14}(+2)$ ions by fast electrons which are known to oscillate between the dees[12] at an energy which is a function of the dee voltage. However, experiments with $C^{12}(+2)$, in an effort to increase the $C^{12}(+6)$ beam, indicate that collision stripping is less likely than multiple bombardment by high-energy electrons.

To verify the existence of these high-energy nitrogen ions in the 60-inch cyclotron, several experiments have been performed in which isotopes of elements with atomic number $Z+7$ have been produced from target elements of atomic number Z and isolated by chemical procedures. It is possible to show that the isotopes found could not have been made from target impurities by projectiles of lower Z than nitrogen.

The production of short-lived alpha-emitting isotopes of astatine ($Z=85$) from gold ($Z=79$) targets has always been a convenient method for monitoring the carbon-ion beam of the 60-inch cyclotron; as a first check for the nitrogen beam, astatine isotopes were produced from platinum ($Z=78$). After it was verified experimentally that carbon-ion bombardment of platinum foils produced no detectable astatine alpha-particle activity from possible gold impurity, these same foils were irradiated in the nitrogen beam. The presence of $_{85}At^{205}$ was established by alpha-particle pulse analysis of its 5.9-Mev alpha particles which decay with a 25-minute half-life. Alpha particles of shorter half-life have also been seen which probably belong to the 7-minute $_{85}At^{203}$. Saturation activities of 10^4 to 10^5 alpha counts per minute are observed in bombardments of 0.0025-inch platinum foils. These astatine isotopes cannot be produced by 40-Mev helium ions from possible bismuth or heavy-element impurities in the target foils; nor is it physically reasonable that helium ions could be accelerated at the high magnetic fields employed here.

Analogous to the production of astatine from platinum is the synthesis of iodine ($Z=53$) from palladium ($Z=46$). Because of the simplicity of rapid radio-iodine chemistry, this procedure also lends itself well to an investigation of the nitrogen-ion beam. Short bombardments of palladium foils have yielded the following activities in the radio-iodine fraction:

Half-life	Relative activity
18.0$\pm$1 min	1000
83.5$\pm$2 min	67
5$\pm$1 day	0.5.

The 83.5-minute radio-iodine is probably I^{121}, produced by the reaction $_{46}Pd^{110}(N,3n)_{53}I^{121}$. The 18-minute activity may be the same as the ~30-minute radio-iodine found by Marquez and Perlman[13] from high-energy helium-ion bombardments of antimony, and assigned by them to either I^{119} or I^{120}. The 5-day tail in the decay curve may correspond to 4.5-day Te^{119}, in which case the 18-minute radio-iodine probably is I^{119}. The reaction would be $Pd^{110}(N,5n)I^{119}$ or $Pd^{108}(N,3n)I^{119}$. It should be mentioned that, previous to the nitrogen-ion bombardments, similar palladium targets were subjected to carbon-ion irradiation, and no activity could be detected in the iodine fractions, though normal yields for the corresponding (C,xn) reactions were found in the tellurium fractions.

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the cooperative effort of the entire staff of the 60-inch cyclotron group, and the continued interest of Professor Glenn T. Seaborg and Professor Ernest O. Lawrence in this program.

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Reactions of U^{238} with Cyclotron-Produced Nitrogen Ions*

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THE acceleration of $N^{14}(+6)$ ions with the Berkeley Crocker Laboratory 60-inch cyclotron[1] has made it possible to study nuclear reactions of these ions with U^{238}.

The following transmutation products have been observed: $99^{247(?)}$, 99^{246}, Cf^{244}, Cf^{246}, $Cf^{247(?)}$, Cf^{248}, Bk^{243}, and other berkelium isotopes not yet identified. The identification of the elements was definitely established by their carrying on lanthanum fluoride precipitates and by their order of elution from a Dowex-50 ion exchange column.

The observed nuclear properties of these nuclides are summarized in Table I.

The nuclides Cf^{244}, Cf^{246}, Cf^{248}, Bk^{243}, and Bk^{245} have previously been observed in this laboratory.[2-4]

The yields of the transcurium nuclides were low even though bombardment currents of 0.1 microampere of $N^{14}(+6)$ ions of energy greater than 100 Mev were available. In three separate experiments a total of 40 alpha-emitting atoms of the 7.3-minute isotope of element 99 were observed to decay in the ion exchange column fraction immediately preceding californium, namely the eka-holmium position. Thus, the element identification is certain though the mass number can only be inferred on the basis of nuclear systematics. By observations of the abundant fission product activity it was found that almost all of the nuclear reactions of nitrogen ions with U^{238} resulted in fission much as in the case of carbon-ion bombardment of the same nucleus.

TABLE I. Nuclides produced by U^{238} plus N^{14} ions.

Nuclide	Half-life	Radiation	Alpha energy (Mev)	Remarks
$99^{247(?)}$	7.3 min	EC(?), α	7.35	
99^{246}	minutes	EC		Observed only through growth of its 1.5-day Cf^{246} daughter
Cf^{244}	45 min	α, EC(?)	7.15	
Cf^{246}	35.7 hr	α	6.75	
$Cf^{247(?)}$	~2.7 hr	EC		
Cf^{248}	225 day	α	6.26	
Bk^{243}	4.6 hr	EC, α	6.72 (30%) 6.55 (53%) 6.20 (17%)	
Bk	days	EC		Observed K x-rays; probably unresolved mixture of Bk^{245} and Bk^{246}

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