$$E^{(2)} = \frac{2m\,U^2 p_0^7}{\pi^6 \hbar^9} \int\limits_0^1 s^2\,ds \left[\int\limits_0^{1+s} p^2\,dp \int\limits_0^{1-s} q^2\,dq + \frac{1}{4s^2} \int\limits_{\sqrt{1-s^2}}^{1+s} p\,dp\,(1-p^2-s^2) \int\limits_{\sqrt{1-s^2}}^{1-s} q\,dq\,(1-q^2-s^2) \right] \frac{1}{p^2-q^2}.$$

Integrating further by parts over s and then carrying out the remaining integration, we obtain

$$E^{(2)} = ({}^6/_{35})\,(3/\pi)^{1/3}\,(11-2\ln 2)\,aN^{1/3}E^{(1)}.$$

Here we have expressed U in accordance with Eq. (2) and set $p_0 = \hbar(3\pi^2 N)^{1/3}$. The result thus obtained is identical with the second-order term in Eq. (21).

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NUCLEAR REACTIONS IN Li^7 AND C^{12} INDUCED BY N^{14} IONS

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In an investigation of the reaction products induced by the bombardment of Li^7 by 15.6-Mev nitrogen ions, activities associated with F^{18}, Ne^{19}, N^{16}, and O^{15} have been found; similarly, an activity associated with Al^{25} has been found in the bombardment of carbon. The production cross sections for the above-mentioned products have been determined. On the basis of an examination of the F^{18}-production cross sections in light elements bombarded by nitrogen ions and the α-particle binding energy in these same nuclei, it is proposed that the F^{18} is formed by capture of an α-particle from the nucleus by the incoming N^{14} nucleus.

NUCLEAR reactions induced in light elements by N^{14} ions have been studied by a number of authors.[1-6] However, in all this work only nuclides with half-lives T greater than 1 min were investigated. The products resulting from the bombardment of Li^7 by N^{14} have not been studied at all.

In the present work we have measured yields for nuclides with $T > 1$ sec produced by bombardment of Li^7 and C^{12} by N^{14} ions. The experiments were carried out with a beam of triply-charged, 15.6-Mev N^{14} ions from a cyclotron; the beam was focussed by two magnetic-quadrupole lenses. The target was placed at the end of a Faraday cylinder. The electric charge deposited by the beam was measured by electronic integration. In these experiments the ion-beam intensity was $4-7 \times 10^{10}$ ions/sec.

The lithium bombardment was carried out with a target consisting of a LiCl layer 70μ thick precipitated from an aqueous solution enriched in Li^7 (the Li^7 content was approximately 99 percent). The

TABLE I

Target nucleus	Reaction product	T	B for nitrogen ions	$\sigma \times cm^2$*
Li^7	F^{18}	112 min	$1.4 \cdot 10^{-7}$	$1.8 \cdot 10^{-26}$
Li^7	Ne^{19}	18.5 sec	$3.1 \cdot 10^{-8}$	$4.0 \cdot 10^{-27}$
Li^7	N^{16}	7.4 sec	$1.1 \cdot 10^{-7}$	$1.5 \cdot 10^{-26}$
Li^7	O^{15}	1.97 min	$1.0 \cdot 10^{-8}$	$1.3 \cdot 10^{-27}$
C^{12}	Al^{25}	7.6 sec	$3.2 \cdot 10^{-9}$	$2.0 \cdot 10^{-28}$

* The cross sections are computed for ions with $E_{lab} = 15.6$ Mev

carbon bombardment was carried out with a graphite target 70μ thick. In both cases the target substrate was a copper slab 70μ thick. The copper end of the Faraday cylinder was 100μ thick. The radiation associated with the induced activity was detected by a MST — 17 end-window β-counter which was placed directly against the end of the cylinder (in this work the solid angle ranged from $0.46 \times 4\pi$ to $0.22 \times 4\pi$). The counter pulses were fed to an amplifier and then to the input of a 10-channel time analyzer in which the pulses were recorded in various channels depending on their relative time delay. By varying the time width of a channel it was possible to measure to 10^{-3} sec and better. In the present work only $T > 1$ sec has been investigated. The analyzer was synchronized with the cyclotron beam and automatically switched on a short time after the beam was switched off.

An analysis of the activity in graphite resulting from the bombardment of Li^7 indicated the presence of nuclides with half-lives of 6.8 sec, 17.5 sec, 2 min, and 130 min. When Li^7 is bombarded by N^{14} formation of the following nuclides with values of T ranging from 5 to 20 sec is possible: F^{20} ($T = 7.35$ sec, $E_{\beta\,max} = 10.4$ Mev); N^{16} ($T = 10.7$ sec, $E_{\beta\,max} = 7$ Mev); Ne^{19} ($T = 18.5$ sec, $E_{\beta\,max} = 2.2$ Mev). For control purposes a decay curve was taken with an aluminum absorber between the counter and the target. The thickness of the absorber (3 mm) was sufficient to stop β radiation from Ne^{19}. In this case the 6.8-sec activity was observed. This result serves as a basis for assuming that when Li^7 is bombarded by nitrogen N^{16} is formed and the F^{20} yield (if it exists at all) is less than 0.1 of the N^{16} yield. The 17.5-sec activity has been assigned to Ne^{19}; the 2-min and 130-min activities have been assigned to O^{15} ($T = 1.97$ sec) and F^{18} ($T = 112$ sec).

The bombardment of C^{12} by N^{14} has been studied in Ref. 2; a 112-min activity (F^{18}), a 15-hour activity (Na^{24}) and 2.6-year activity (Na^{22}) were found. In the present work the short-lived activities were studied. A 7.4-sec activity, apparently due to the $C^{12}(N^{14}, n)Al^{25}$ reaction was observed.

Extrapolating the decay curves to the origin, introducing corrections for β-ray absorption in the target, substrate, and end of the Faraday cylinder, and introducing solid-angle corrections we have determined the yields for the various nuclides formed in N^{14} reactions. In Table I are shown the yield values B for thick targets, referred to a single nitrogen ion. In this same table are shown the cross sections σ for the various reactions which result in the formation of the nuclides shown in the table. To compute the values of σ, starting from the values of B determined in the experiments, one must know the excitation function $\sigma(E)$ and the stopping power of the target material for nitrogen ions. We have compared the experimentally determined excitation functions[2-4] for the reactions

$$Be^9(N^{14}, He^5)F^{18}, \quad (1)$$

$$B^{10}(N^{14}, Li^6)F^{18}, \quad (2)$$

$$C^{12}(N^{14}, Be^8)F^{18}, \quad (3)$$

$$O^{16}(N^{14}, C^{12})F^{18} \quad (4)$$

and are convinced that these functions are very much the same for energies E less than the height of the Coulomb barrier E_b; for nitrogen-ion interactions with Be^9 and B^{10} the excitation functions are essentially identical. Hence, in computing σ for reactions occurring in the bombardment of lithium by nitrogen ions we have used the $\sigma(E)$ curve for the reactions in (1) and (2) published in Refs. 3 and 4; in the carbon case the $\sigma(E)$ curve for reaction (3) given in Ref. 2 has been used. The stopping power for nitrogen ions was computed by converting the range-energy curves for α-particles using the method proposed by Lonchamp.[7] We have obtained the following results: nitrogen ions with $E \leq 15.6$ Mev in LiCl, $dE/d\rho x = 6.1$ Mev-mg^{-1}-cm^2; in graphite $dE/d\rho x = 7.6$ Mev-mg^{-1}-cm^2.

The high value of the F^{18}-production cross section in Table I is noteworthy. An anomalously high F^{18} yield is also noted in bombardment of certain other elements by nitrogen ions. It is possible that F^{18} formation takes place as the result of the capture of an α particle from the target nucleus by the incoming N^{14} nucleus as in "inverse stripping" reactions in which the incoming nucleon can cause the ejection of another nucleon from the nucleus and continue on in the form of a deuteron. It is apparent that with a re-

TABLE II

Target nucleus	E_{bind}, Mev	E_B, Mev	σ, cm²	Reference
Li^7	2.5	5.0	$1.8 \cdot 10^{-26}$	Present work
Be^9	2.2	6.4	$1.0 \cdot 10^{-25}$	[3]
B^{10}	4.4	7.9	$6.5 \cdot 10^{-27}$	[4]
C^{12}	7.4	9.2	$1.0 \cdot 10^{-27}$	[2]
N^{14}	11.6	10.5	*	
O^{16}	7.2	11.7	$1.5 \cdot 10^{-27}$	[4]
Al^{27}	10.0	17.4	**	

* Activity due to F^{18} production is not observed.[5]
** Activity due to F^{18} production is observed but the value of σ is not given.[6]

action mechanism of this kind a larger value of the F^{18}-production cross section will be observed when the nitrogen ions bombard nuclei with smaller α particle binding energies (E_{bind}). In Table II we compare nitrogen-ion induced F^{18}-production cross sections and values of α particle binding energy in light nuclei. In order to compare the results, the values of σ are taken for collision energies equal to the height of the Coulomb barrier.

It was obvious from Table II that σ decreases as E_{bind} increases.

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A STUDY OF SLOW μ MESONS IN THE STRATOSPHERE BY THE METHOD OF DELAYED COINCIDENCES

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A study has been made of the altitude dependence of μ mesons of ~ 100 Mev up to altitudes of about 25 km at 51° and 31° N latitude. The μ-meson production spectrum in the atmosphere has been measured at these latitudes.

EXPERIMENTS on the altitude dependence of slow μ mesons by the method of delayed coincidences were carried out by Sands[1] and Conversi[2] in airplanes at altitudes up to ~ 10 — 11 km. In the present experiment the altitude dependence of slow μ mesons has been studied using that method in balloon flights up to the altitude of ~ 25 km at 51° and 31° N geomagnetic latitude.

The counter arrangement used is shown in Fig. 1. The counter trays T_1 and T_2, separated by a Pb absorber 5 cm thick, formed a telescope. The two groups of counters marked "del" detected delayed particles. The counters of the groups A and B were connected in parallel and the anti-coincidences (A-B) were recorded. The mesons stopped in the graphite block C 7 cm in thickness.

The array detected μ mesons with kinetic energies of 100 — 115 Mev. The "del" counters were oper-