Triton-Induced Reactions*

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By using tritons from pile-irradiated Li, the reactions $O^{18}(t,n)F^{20}$, $O^{18}(t,\alpha)N^{17}$, and $N^{15}(t,p)N^{17}$ have been observed, and their relative yields obtained. The cross section at about 2.7 Mev of the well-known reaction $O^{16}(t,n)F^{18}$ was also measured and is roughly 0.5 barn.

THE technique of observing triton-induced reactions by mixing lithium with a target element and irradiating in a pile is by now well known. The slow-neutron reaction $Li^6(n,\alpha)H^3$ yields 2.8-Mev tritons. With Li_2CO_3, the $O^{16}(t,n)F^{18}$ reaction was observed during the Manhattan Project work.[1] Iwerson *et al.*[2] used Li-Al and Li-Mg mixtures and observed the $Al^{27}(t,p)Al^{29}$ and $Mg^{26}(t,p)Mg^{28}$ reactions, and searched for, but did not find, the $P^{31}(t,p)P^{33}$ reaction. In the present work, the reactions $O^{18}(t,n)F^{20}$, $O^{18}(t,\alpha)N^{17}$, and $N^{15}(t,p)N^{17}$ were observed, and the cross section of the $O^{16}(t,n)F^{18}$ reaction at about 2.7 Mev was obtained.

$O^{18}(t,\alpha)N^{17}$

Li_2CO_3 and an aqueous solution of LiF were each irradiated in the BNL reactor for about 20 seconds, and a BF_3 counter, set up at the pneumatic tube which carried the samples into and out of the reactor, was used to detect the 4.1-second delayed neutron activity characteristic of N^{17}.[3] No such activity was found in control samples containing either Li or O without the other. [The reaction $O^{17}(n,p)N^{17}$ could occur, but was not detected because of the extremely low abundance of O^{17} and the low fast-neutron flux.] Consideration of possible triton- or alpha-induced reactions in oxygen leading to N^{17} shows that the only reaction energetically possible is $O^{18}(t,\alpha)N^{17}$, with a Q-value of 3.8 Mev.[4]

Banks[5] has measured the saturated yield of F^{18} from the reaction $O^{16}(t,n)F^{18}$ in Li_2CO_3 as 2 millicuries per gram Li_2CO_3 under identical irradiation conditions in the pile as the present work. By calibrating the BF_3 counter with a Po-Be source of known strength, the saturated N^{17} yield was measured as 0.8 ± 0.3 microcurie per gram Li_2CO_3; by correcting for the relative abundances of O^{18} and O^{16}, the N^{17} yield per target atom is therefore obtained as about 0.2 times the F^{18} yield.

$O^{18}(t,n)F^{20}$

The BF_3 counter was replaced by a NaI(Tl) scintillation counter. The 12-sec 1.6-Mev gamma ray of F^{20} was observed. The yield of this reaction was estimated by "doping" the Li_2CO_3 with known small amounts of LiF, and measuring the F^{20} activity generated by the reaction $F^{19}(n,\gamma)F^{20}$. This, together with the known thermal-neutron capture cross section of F^{19} and the known thermal-neutron flux in the reactor, permitted an estimate of the absolute efficiency of the scintillation counter. The undoped Li_2CO_3 was spectrographically analyzed for fluorine contamination; the amount detected could have accounted for only 1.5% of the observed F^{20} activity. The yield of the reaction $O^{18}(t,n)F^{20}$ was 23 ± 4 microcuries per gram Li_2CO_3, or (6 ± 1) times the $O^{16}(t,n)F^{18}$ yield per target atom, and about 30 times the N^{17} yield from the $O^{18}(t,\alpha)N^{17}$ reaction.

$N^{15}(t,p)N^{17}$

The sample was Li_3N, and again the 4.1-second delayed neutron activity was observed. The yield per gram Li_3N is about the same as the yield per gram Li_2CO_3 in the reaction $O^{18}(t,\alpha)N^{17}$. Since there are both more atoms of Li^6 and more target atoms (N^{15} or O^{18}) per gram Li_3N than per gram Li_2CO_3, this result implies a somewhat higher effective cross section for the reaction $O^{18}(t,\alpha)N^{17}$ than for the $N^{15}(t,p)N^{17}$ reaction.

The arrangement for the $O^{16}(t,n)F^{18}$ cross-section measurement was somewhat different than that mentioned above. A thin source of Li_3N was prepared by placing Li_3N powder on Scotch tape. Two sheets of Mylar (of order 0.6 mg/cm^2) separated by thin Al foil were placed over the Li_3N. This arrangement presumably insured that tritons of somewhat higher energy would induce the reactions in the oxygen in the Mylar, rather than the strongly degraded tritons available in the chemical compounds or mixtures. The estimated average energy of tritons in the Mylar sheet next to the Li_3N was 2.7 Mev; the thickness of the Al foil was chosen so as to make the average energy of the tritons in the further Mylar sheet about 2.1 Mev. A Geiger counter was used to observe the 112-min F^{18} positron activity of the Mylar sheets; this gave the ratio of the cross section at 2.7 Mev relative to 2.1 Mev and, by comparison with Jarmie's curves,[6] the absolute cross section at 2.7 Mev. This is 0.5 ± 0.2 barn. The measurement is a rough one, with energy uncertainties of at least ±0.1 Mev.

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[1] Knight, Novey, Cannon, and Turkevich, *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, New York, 1951), Paper No. 326, National Nuclear Energy Series, Plutonium Project Record, Vol. 9, Div. IV, Book 3, p. 1916.
[2] Iwerson, Koski, and Rasetti, Phys. Rev. **91**, 1229 (1953).
[3] L. W. Alvarez, Phys. Rev. **75**, 1127 (1949).
[4] The mass of N^{17} is taken as 17.01385 amu [R. A. Charpie *et al.*, Phys. Rev. **76**, 1255 (1949)].
[5] H. O. Banks, Jr., Nucleonics **13**, No. 12, 62 (1955). We are indebted to Dr. Banks for communicating this result to us prior to publication.
[6] N. Jarmie, Phys. Rev. **98**, 41 (1955).