1) D. Long, M. Sternheim and R. Silbar, "Simplified Intranuclear Cascade Approach to Inclusive (p,π^-xn) Reactions. Preprint, Oct. 1981.

2) J. Clark, P. Haustein, T. Ruth, J. Hudis, A. Caretto, Jr., and W. Gibbs, "Measurement of Inclusive π^- Production with 200 MeV Protons: A Radiochemical Study of the ^{209}Bi(p,π^-xn)$^{210-xn}$At Reactions," Preprint, October 1981.

ACTIVATION MEASUREMENTS OF THE ^{208}Pb(^{3}He,π^-xn)$^{211-xn}$At REACTION

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There have been several recent experimental[1-4] and theoretical[5,6] studies of pion production with complex projectiles below the threshold for production in free nucleon-nucleus reactions. Wall et al.[1] measured the ^{208}Pb(^{3}He,π°) inclusive cross section at 200 MeV to be 6.0 x 10^{-2} nb/sr-MeV, yielding a total cross section of 4.5 nb for 6 MeV pions. Doubly-coherent pion production[2] by 910 MeV ^{3}He on ^{6}Li yielded 0.42 x 10^{-3} nb/sr for the differential cross section. The heavy ion study by Benenson et al.[3] has prompted several new investigations of pion production below the free threshold. More recently, Le Bornec et al.[4] have studied coherent pion production near threshold in ^{3}He-^{3}He reactions at 270 and 283 MeV incident energies. In particular, they observed the ^{3}He(^{3}He,π^+)^{6}Li reaction to discrete states with sizeable cross sections. Klinginbech, Dillig and Huber[5] have developed a microscopic model for the complete fusion of two nuclei and subsequent pion production. The model adequately describes the ^{3}He(^{3}He,π^+)^{6}Li process near 280 MeV. Bertsch[6] has calculated the (^{3}He,π) reaction cross section at 70 MeV/nucleon in an independent particle model. The calculation gives zero if collective Fermi motion is neglected and about 1 nb if the internal momentum of the ^{3}He nucleons is included.

In the present study we have measured the ^{208}Pb(^{3}He,π^-xn)$^{211-xn}$At cross sections in the energy range of 130-230 MeV using activation and radiochemical techniques. The Astatine was radiochemically separated according to the procedure of Bochvarova et al.[7] from the activated, enriched ^{208}Pb targets in separation times of 1-3 hours with estimated chemical yields of 20%. A source was made of the final activity by an electrochemical deposit of the At on a 1 cm diameter Ag foil. All sources were counted in a standard geometry using alpha spectroscopy. The results of our first two shifts of beam time are given in Table I. The results differ somewhat from what we reported last year[8] due to a better estimate of the chemical yield. The relative uncertainty in these measurements are ±15-30%, whereas the absolute uncertainty is estimated at ±50%. Our detection limit is about 0.1-0.5 nb. The below threshold measurement at 130 MeV did not produce a detectable amount of Astatine.

TABLE I

E_{He}(MeV)	σ_{207}(nb)	σ_{211}(nb)	Target mg/cm^2
130	<0.5	<0.5	10
158	9.7	8.0	63
198	5.3	7.6	144
200	7.8	11.6	71
230	<2.5	4.4	75

Clearly, we are observing the production of ^{211}At and ^{207}At at the 1-10 nb level. The results are essentially in agreement with earlier (^{3}He,π°) results at 200 MeV, but also indicate that in addition to the doubly-coherent ^{211}At production there is also considerable ^{207}At production. It is difficult to understand how these nuclei could be produced through secondary two-step processes, i.e. through the $(^3He,^6Li)$ pick up reaction with subsequent $^{208}Pb(^6Li,xn)^{214-xn}At$ reactions. Our below threshold results indicate that this secondary reaction contribution is small.

On the other hand, the production of π^- from the projectile single-particle neutron in ^3He is expected to be doubly-coherent to the ^{211}At bound states. Direct π^- knockout from the target pion field would account for the π^-xn channels as observed in the $^{209}Bi(p,\pi^-xn)$ study of Experiment #20 at IUCF.[9]

Our plans are to complete the study by measuring the cross sections at two or three energies below 200 MeV and at 270 MeV. These data will be compared with the microscopic model of Klingenbeck, Dillig and Huber.[5]

1) N.S. Wall, J.N. Craig and D. Ezrow, Nucl. Phys. A268, 459 (1976).

2) E. Aslanides et al, Phys. Rev. Lett. 43, 1466 (1979).

3) W. Benenson et al, Phys. Rev. Lett. 43, 683 (1979).

4) Y. LeBornec, L. Bimbot, N. Koori, F. Reide, A. Willis, N. Willis and C. Wilkin, to be published in Phys. Rev. Lett. (1982).

5) K. Klingenbeck, M. Dillig and M. Huber, to be published in Phys. Rev. Lett (1982).

6) G.F. Bertsch, Phys. Rev. C 15, 713 (1977).

7) M. Bochvarova et al, Soviet Radiochem. 14, 899 (1972).

8) T.E. Ward et al, IUCF Scientific and Technical Report 1980, p. 63.

9) T. Ward, K. Pitts, D. Friesel, P. Singh, J. D'Auria, M. Dombsky, G. Sheffer, and J. Clark, contribution to this Annual Report.