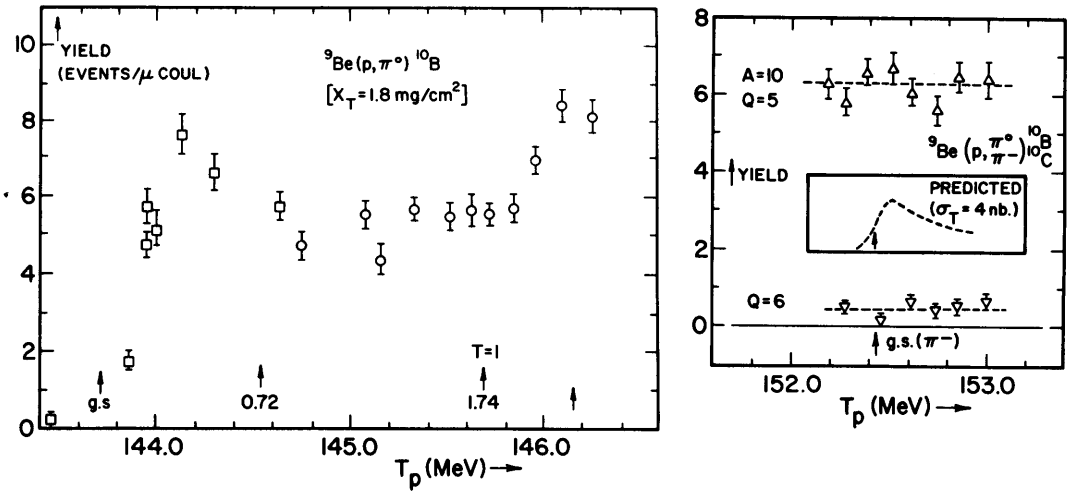


*Figure 1. (left) Excitation function for the recoil yield for the $^{9}Be(p,\pi^{o})^{10}Be$ reaction. Arrows show the threshold for various excited states of $^{10}Be$. (right) Excitation function search for the threshold for the $^{9}Be(p,\pi^{-})^{10}C$ reaction. The inset figure shows the predicted energy dependence of the cross section at threshold.*

yield for the several, particle-stable states of $^{10}B$, as well as the $(p,\pi^{-})$ process of interest, and alternatively set for $6^{+}$ recoils to reject the $^{10}B$ background. Preliminary analysis of this data gives an upper bound to the $(p,\pi^{-})$ yield which is somewhat smaller than expected by extrapolation downward in energy, from the single known cross section value from Uppsala, using the penetrability and phase space functions which describe the $^{10}B(p,\pi^{+})^{11}B$(g.s.) energy dependence.[3]

This apparatus has been dismantled to make room for the QQSP spectrograph. The final results of the measurement and a full description of the technique will be prepared for publication.


1) R.E. Marrs, R.E. Pollock, and W.W. Jacobs, Phys. Rev. C 20, 2308 (1979).

2) M. Pickar, IUCF Experiment 18, reported elsewhere in this volume. See also M. Pickar, et al., Bull. Am. Phys. Soc. 24, 819 (1979)

3) P.H. Pile et al., Phys. Rev. Lett. 42, 1461 (1979).


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


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The $^{208}Pb(^{3}He,\pi^{-}xn)^{211-xn}At$ reaction is being studied radiochemically by measuring the residual α-activity of the astatine isotopes. A measurement of the $(^{3}He,\pi^{-})$ yield at energies well below the free nucleon-nucleon pion threshold can be used to test for collective effects in pion production using complex projectiles. Bertsch[1] has calculated pion-production in heavy ion collisions and has shown that neglecting collective effects, the $(^{3}He,\pi)$ reaction cross section at 70 MeV/nucleon gives zero and by including the internal momentum of the nucleons in $^{3}He$, it yields ∿ 1 nb. Wall et al.[2] reported a $^{12}C(^{3}He,\pi^{o})$ cross section of ≤ 0.007 nb/sr-MeV at 200 MeV bombarding energy, yielding a total cross section of the order of ≤ 1 nb. More recently Benenson et al.[3] have measured the $\pi^{+}/\pi^{-}$ yields produced by $^{20}Ne$ heavy ions from 85-400 MeV/nucleon on a number of targets. Those results compare favorably with the Bertsch type calculation and indicate that the production of pions with complex projectiles is consistent with his simple model.

Sources of astatine were produced through the $^{208}Pb(^{3}He,\pi^{-}xn)^{211-xn}At$ reaction with 158.8 MeV $^{3}He$ on a 10 mg/cm$^2$ enriched $^{208}Pb(NO_3)_2$ target. The beam current was about 230 particle nanoamps DC-averaged over 2-3 hr runs. Astitine was radiochemically separated using the procedure of Bochvarova et al.[4] Briefly the procedure is to separate At using a tellurium metal column which gives excellent separation from other radioelements inclduing iodine from fission. In the final step At is spontaneously electroplated onto silver foils (1 cm dia.). The At isotopes are uniquely determined by their α- or γ-radiation. Separation times of 1-2 hr and chemical yields of ∿35% are typical.[5]

In Fig. 1 are shown results of our first excitation measurement. The α-spectrum was obtained using a 400μm thick Ortec Si surface barrier detector with a 4096 Channel Canberra 8180 multichannel analyzer. Although the count rates were quite low (∿ 0.2-0.3 cpm) the high resolution and low background allow unambiguous identification. Two At isotopes clearly identified are $^{207}At$ (1.8 hr), $E_\alpha$=5.759 MeV (10%) and $^{205}At$ (26 min), $E_\alpha$= 5.901 MeV (10%). Production cross sections of 1.9 nb and 0.5 nb were calculated for $^{207}At$ and $^{205}At$, respectively. Limits of $\leq$ 0.07 nb and $\leq$ 0.7 nb were deduced for $^{209}At$ (5.4 hr), $E_\alpha$=5.647 MeV (4.1%) and $^{206}At$ (31 min), $E_\alpha$=5.703 MeV (1%), respectively.

The kinematic threshold for the $^{208}Pb(^{3}He,\pi^{-})^{211}At$ reaction is 134.8 MeV. Measurement of the At yield

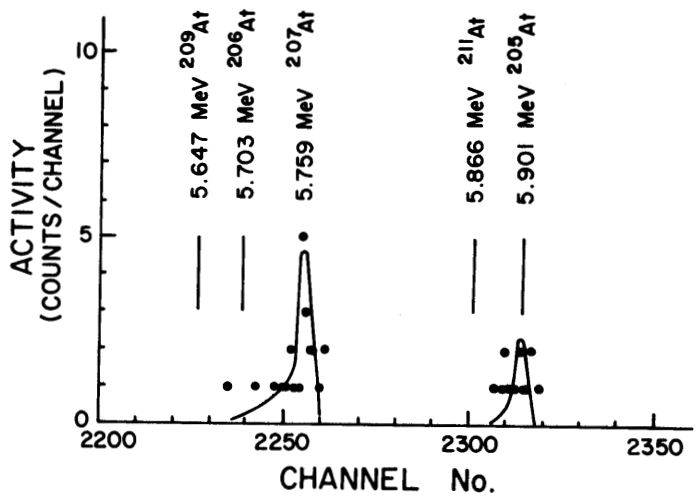


*Figure 1. Singles alpha decay spectrum of the radiochemically separated astatine fraction from 158.8 MeV $^{3}He$ bombardment of $^{208}Pb$. The peak shapes are drawn in to guide the eye.*

below threshold remain to be performed before estimates of secondary contributions can be made. It is interesting to note that our first results indicate substantial yields peaking at four neutrons to six neutrons out. Secondary Li ejectiles of 50-100 MeV on $^{208}Pb$ could produce those isotopes; however, the secondary energy spectrum could also be expected to produce $^{209}At$ in good yield. Clearly further measurements are in order.


1) G. Bertsch, Phys. Rev. C15, 713 (1977).

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

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

4) M. Bochvarova, D.K. Tyung, I. Dudova, U.V. Norseev, and V.A. Khalkin, Soviet Radiochemistry 14, 889 (1972).

5) J. Clark, Carnegie Mellon University, private communication.