MEASUREMENT OF TOTAL (p,π) CROSS SECTIONS THROUGH RESIDUAL ACTIVITY

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The total reaction cross section for the $^{209}Bi(p,\gamma+\pi^{\circ})^{210}Po$ reactions was measured in the energy range of 62-200 MeV at IUCF and 183-480 MeV at TRIUMF. The measurements were made using activation techniques, radio-chemistry and alpha-particle spectroscopy. The total cross sections were measured at the 1-10 μb level above the threshold with an absolute uncertainty of about ±30%. The relative uncertainty (due mainly to statistics) was typically ±12%. The results of the pion-production excitation function were fit satisfactorily using the two-nucleon model of Manfred Dillig. These results were published in Physical Review C 24, 588 (1981).

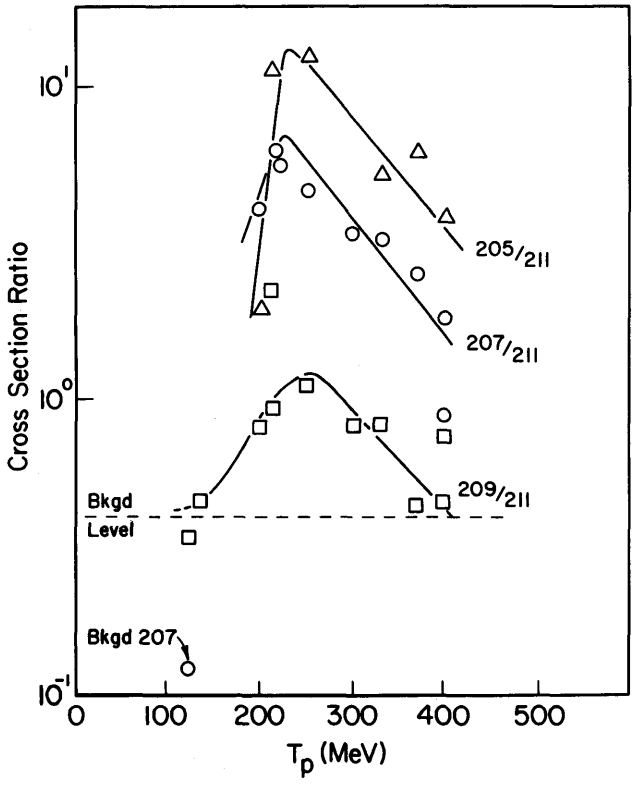

Figure 1. Relative cross sections of Astatine isotopes produced in the $^{209}Bi(p,\pi^{-}xn)^{210-x}n$At reactions at incident energies of 120-400 MeV.

In addition to the (p,π°) study, the (p,π⁻xn) reaction on Bismuth was also studied radiochemically using similar techniques in the energy range of 120-400 MeV. These preliminary results indicate substantial π^{-} production of 1-15 μb per mass number at proton energies of 200-220 MeV. These preliminary results are shown in Fig. 1 plotted as the cross section ratio versus the incident proton energy. The background level for secondary production of ^{211}At was about 1-2 μb, for ^{209}At it was about 0.5-1.0 μb and for ^{207}At it was about 0.1-0.2 μb. The At products produced in the (p,π⁻xn) reactions at these energies are 3 to 5 neutrons removed from the doubly-coherent residue, ^{210}At. These results are qualitatively in agreement with recent theoretical[1,2] and experimental[2] studies that are investigating the energy dependence of the (p,π⁻xn) total reaction cross section in terms of a cascade-isobar model[1] or pion knockout model[2].

The preliminary results shown in Fig. 1 indicate that the results below 200 MeV are critical since they cover the threshold region where model predictions vary the most. This experiment has also been approved at TRIUMF (E189) and at LAMPF (E679) where we hope to study these reactions up to 800 MeV incident proton energy. The results suggest that a multinucleon process is important in π^{-} production, as indicated by a strong dependence on the nuclear level density of particle-hole states.

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 $^{209}Bi(p,\pi^-xn)^{210-xn}At$ Reactions," Preprint, October 1981.

ACTIVATION MEASUREMENTS OF THE $^{208}Pb(^3He,\pi^-xn)^{211-xn}At$ 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 $^{208}Pb(^3He,\pi^\circ)$ inclusive cross section at 200 MeV to be 6.0×10^{-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 ^3He on ^6Li yielded 0.42×10^{-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 ^3He-^3He reactions at 270 and 283 MeV incident energies. In particular, they observed the $^3He(^3He,\pi^+)^6Li$ 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 $^3He(^3He,\pi^+)^6Li$ process near 280 MeV. Bertsch[6] has calculated the $(^3He,\pi)$ 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 ^3He nucleons is included.

In the present study we have measured the $^{208}Pb(^3He,\pi^-xn)^{211-xn}At$ 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

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

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.

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 $(^3He,\pi^\circ)$ results at 200 MeV, but also indicate that in addition to the