Production of Neutron Deficient Plutonium Isotopes

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Production of three highly neutron-deficient isotopes of plutonium, ^{229}Pu, ^{230}Pu and unknown ^{231}Pu, was attempted with the highly assymetric reaction ^{233}U(^{3}He,5-7n). An attempt was made to measure half-lives, alpha-decay energies and alpha/electron capture branching ratios for the three isotopes. Until Andreyev et al. identified ^{228}Pu, ^{229}Pu and ^{230}Pu, the lightest plutonium isotope known was ^{232}Pu.[1,2] In these experiments, ^{229}Pu and ^{230}Pu were produced in a ^{208}Pb(^{26}Mg,4-5n) reaction. Production of ^{228}Pu was achieved by a similar reaction: ^{208}Pb(^{24}Mg,4n). Andreyev et al. were able to measure alpha-decay energies of these new isotopes, but could not measure half-lives or branching ratios.

The ^{233}U(^{3}He,5-7n) experiment was performed to study both decay properties and reaction mechanisms. Knowledge of decay characteristics of highly neutron-deficient plutonium isotopes is valuable to the study of electron capture delayed fission (ECDF) of light americium isotopes, since these plutonium isotopes are members of the americium decay chains. Determination of plutonium masses and decay Q-values aids estimation of electron-capture Q-values for potential ECDF precursors, like ^{230}Am. By studying the reaction mechanism involved in different systems, investigators can design better experiments. The two main criteria in designing an experiment to study exotic nuclei are high production rate of the nuclide under investigation and low production rate of interfering background activity. Comparisons between the lead target heavy-ion beam system used by Andreyev et al. and the actinide target light-ion beam system used in this experiment will aid in designing future experiments involving neutron-deficient actinides.

Eleven ^{233}U targets were mounted in the light-ion multiple target system.[3] The reaction products were transported via a helium jet system from the reaction chamber and deposited on polypropylene foils in our MG rotating wheel system. It can be rotated to place the foils successively between six pairs of surface barrier detectors. Identification of a plutonium isotope relies on observation of the alpha decay of members of its decay chain. Measurements were attempted at three cyclotron energies: 40, 50 and 60 MeV in the laboratory frame. The helium ions lose less than 1 MeV in interactions with the cyclotron window and the target system itself. The ^{231}Pu, ^{230}Pu and ^{229}Pu cross sections were predicted to peak at these energies, respectively.

Many alpha-decay chains were observed. However, large amounts of interfering activity were produced. This activity may have been due to (^{3}He,pxn) and (^{3}He,αxn) reactions that directly yield neptunium and uranium isotopes. These high background levels and relatively long half-lives of the plutonium, neptunium, and uranium isotopes at the beginning of the deay chains made determination of half-lives and branching raios of the light plutonium isotopes impossible. These problems will be avoided in the future by chemically separating plutonium, neptunium and uranium reaction products from each other before attempting detection of alpha-decay.

Footnotes and References

1. A.N. Andreyev et al., Z. Phys. A, 337, 231 (1990).
2. A.N. Andreyev et al., Z. Phys. A, 347, 225 (1994).
3. H.L. Hall, M.J. Nurmia and D.C. Hoffman, Nucl. Instrum. Meth., A276, 649 (1989).