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P R O P O S A L

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The ASTERIX Collaboration

Re: Study of Neutron-deficient Nuclei Between U (Z = 92) and Pb (Z = 82) Using a Helium Jet Transport Technique

(Parasitic to ISOLDE)

1. Introduction

ISOLDE has been able to study short-lived isotopes of a great number of elements. Short-lived neutron-deficient isotopes of the elements Np, U, Pa, Th, Ac, and some of their alpha-decay products, however, have so far not been accessible to studies of nuclear spectroscopy. Also, determinations of their cross sections of production in the spallation reactions are still to be performed.

Recent advances in the helium-jet transport technique make such studies feasible[1,4-6], in particular with the upgraded beam of the CERN Synchrocyclotron. Therefore, we propose to study some products of the reaction of 600-MeV protons on ^{232}Th, ^{233}U, and ^{238}U.

2. Proposed Experiments

Two types of experiments will be carried out:

a) Decay Studies and Decay Systematics

The decay properties of the following short-lived (0.5 s $< T_{1/2} <$ 5 min) neutron-deficient nuclei will be studied: ^{227}U, $^{224-226}Pa$, $^{223-224}Th$, $^{222-223}Ac$, and their alpha

decay products (88 $\geqslant$ Z $\geqslant$ 83) with half-lives in the order of microseconds to seconds. These nuclides are to a large extent not accessible to investigations with ISOLDE facilities. The study of their decay is of special interest as the shape of these nuclei ranges from strongly deformed near uranium to almost spherical near lead.
The investigation will be made with the aim of following systematic trends in the level structure of these nuclei. In particular, the study of single-particle levels in odd nuclei in the region of radium, i.e. at the beginning of the deformation, should give information on the relative position of these levels as a function of the deformation parameter. As compared to corresponding transitional nuclei of the lanthanides, in even nuclei of this region extremely low-lying octupole states are found. Provided, these states are populated by alpha decay, one would possibly be able to look for the influence of the Coriolis interaction between different octupole states on the position of the levels and on transition probabilities.
If the transport of the reaction products proves to be fast enough, nuclides below the 126-neutron shell, e.g. ^{215}Th and $^{212-214}$Ac may also be studied. - Finally, we will search for beta-delayed spontaneous fission activities using mica detectors.
The experiment will mainly involve singles alpha, alpha-alpha, alpha-gamma, and alpha-Xray spectroscopy.

b) Nuclear Reaction Studies
Relative yields of individual spallation products will be determined from their alpha decay data. The detection and data handling technique will be similar to that used by Molzahn[2] during ISOLDE I. A comparison of relative yields from ^{233}U and ^{238}U targets will show whether a neutron-deficient target (^{233}U) will give higher yields of very neutron-deficient spallation products than a target nuclide

on the line of beta stability (^{238}U). This question cannot be easily answered on the basis of existing nuclear models but is of practical interest for ISOLDE target development studies.

3. Target Arrangement and Helium Jet

The target consists of a stack of metal foils of the desired target element on aluminum backing. The target itself is placed in a pressure chamber ($p \leq 2$ atm). If spallation products, leaving the target via nuclear recoil, hit on clusters[1,3] or aerosols, they may become attached to them and be transported by the helium stream through a capillary to a remote low-background area for counting in about one second. As there will be no mass-selective separation step involved, the detection and identification of the products must be done by their alpha decay characteristics and genetic relations of the appropriate decay series.

4. Equipment

All the equipment, i.e. the pumps for the helium jet, the target and the detection system along with the necessary electronics will be supplied by the experimenters. We would like to set up the equipment soon after the start of ISOLDE II, i.e. in September 1974.

5. Requirements

A position for the target chamber in the ISOLDE proton-beam line is needed. (It has been suggested to use the beam-dump tunnel behind the ISOLDE target). Plastic tubes (for the helium jet) will connect the target chamber with the detector chamber and the pumps. The detection system with the electronics, the pumps, etc. would have to be put up in caravans outside the ISOLDE hall, preferably in the court-yard of the SC near the ISOLDE building.

We would need electrical power for the pumps and the electronics (25 KVA), water for cooling the target chamber, and temporarily some office space.
The experiment will be run fully parasitic to ISOLDE. Hence, there will be no special beam-time requests.

References

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Appendix

As an example, the equilibrium decay rate of ^{225}Th produced in the reaction ^{232}Th(600 MeV p, p7n) is estimated on the basis of the following assumptions:

cross section (σ):	8 mb	Ref. 2
proton flux (ϕ):	10^{13} s^{-1}	
effective target thickness for one target foil (d):	10 $\mu g/cm^2$ *) $\hat{=}$ 2.6×10^{16} atoms/cm^2	3,7
estimated transport efficiency over a distance of 30 m (ε):	15 %**)	1,3
counting efficiency for the transported activity (δ):	30 %***)	3

$$\frac{dN}{dt} = \sigma \phi d \varepsilon \delta \approx 10^2 \ s^{-1} \quad ****)$$

With the use of more than one target foil and a higher transport efficiency (see below), it might be possible to study nuclides with cross sections as low as 1μb, i.e. decay rates of about 0.1 α/s. The yield curve would then cover three to four orders of magnitude in production cross section.

*) The target thickness and the distance between two target foils - or between a target foil and the wall - is chosen so as to allow the low-energy spallation products to be stopped in helium, but to have the high-energy fission fragments ($E \gg 1$ MeV) to be caught in solid material.

**) 15 % is a lower limit. Usually 50 to 70 % can be achieved.

***) This relatively high counting efficiency will allow coincidence studies in a comparatively low beta-activity environment. This will be a major improvement over the work in Ref. 2, where due to the high beta- and gamma-radiation field the distance between target and detector had to be rather long so that the counting efficiency was only of the order of 0.001..

****) This calculated decay rate agrees with decay rates observed in a helium jet experiment at the Berkeley Bevatron (6 GeV) (Ref. 6).