Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

Submitted to Zeitschrift für Physik A

BETA-DELAYED PROTON PRECURSORS WITH $59 \leq Z \leq 62$

P.A. Wilmarth, J.M. Nitschke, P.K. Lemmertz,
and R.B. Firestone

January 1985

NUCLEAR SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-19000

Beta-Delayed Proton Precursors with $59 \leq Z \leq 62$

P.A. Wilmarth, J.M. Nitschke, P.K. Lemmertz, and R.B. Firestone

Nuclear Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

Abstract:
The new, beta-delayed proton emitters ^{128}Pr($3.2^{+0.5}_{-0.4}$ s), ^{130}Pm($2.2^{+0.6}_{-0.4}$ s), and ^{132}Pm($5.0^{+0.8}_{-0.6}$ s) have been observed at the on-line isotope separator OASIS. Also studied were ^{129}Nd and ^{133}Sm.

Our on-going study of the decay properties of very neutron-deficient lanthanides has led to detailed information about beta-delayed proton emitters with $59 \leq Z \leq 62$. The isotopes were produced at the SuperHILAC's on-line isotope separator OASIS [1] in reactions of ^{40}Ca projectiles on ^{92}Mo and ^{96}Ru targets enriched to >95%. Decay studies were carried out in a low background spectroscopy laboratory. The isotope of interest was passed through a slit in the focal plane of the mass separator, transported ionoptically to a fast cycling tape, and periodically positioned between a silicon charged particle telescope, a HPGe x-ray detector, and a GAMMA-X Ge detector. Decays involving beta-delayed gamma rays and protons along with any coincident positrons, x-rays and gamma rays were measured event-by-event and written to computer tape for subsequent replay and analysis.

The preliminary results of our recent work are summarized in Tables 1 and 2.

A=128: In a previous experiment a delayed proton activity was observed at this mass number with a half-life of 4 ± 2 s [2]. This activity was incorrectly assigned to ^{128}Nd on the basis of cross-section and half-life predictions. We repeated this measurement to detect the characteristic x-rays associated with electron capture delayed proton emission which provide an unambiguous Z identification. A weak beta-delayed proton activity with a half-life of $3.2^{+0.5}_{-0.4}$ s observed in coincidence with Ce K x-rays can now be unambiguously assigned to the new isotope ^{128}Pr. No evidence for beta-delayed proton decay from ^{128}Nd was observed. ^{128}Pr was also identified by its beta decay to the known rotational levels in ^{128}Ce. The decay analysis of the gamma rays from the de-excitation of the 2+ and 4+ levels in ^{128}Ce yields a half-life of 3.0 ± 0.1 s in good agreement with the proton half-life, but considerably shorter than the value of 9 s predicted by the gross theory of beta decay [3].

A=129: A β-delayed proton activity with a half-life of 5.9 ± 0.6 s at this mass was assigned to ^{129}Nd by Bogdanov et al. [4] based on systematics for delayed proton emission. We decided to confirm this result since the high cross section for production of this isotope enabled a thorough study of its decay properties. A strong β-delayed proton activity was indeed observed and a more precise half-life of 4.9 ± 0.2 s was determined. Electron capture decay to proton unbound levels in ^{129}Pr gave rise to characteristic Pr K x-rays in coincidence with protons which confirms the assignment of ^{129}Nd. A strong feeding to the known 2+ level of ^{128}Ce was observed via a prominent gamma ray at 207.3 keV in coincidence with the protons. A comparison of the proton branches to the ground and first two excited states in ^{128}Ce with statistical model calculations indicates that a ground state spin of 5/2+ as predicted by Seeger and Howard [5] for ^{129}Nd is compatible with the experiment. The statistical model results do not allow an unambiguous parity assignment in this case.

A=130: A weak β-delayed proton activity with a half-life of $2.2^{+0.6}_{-0.4}$ s was observed at this mass. The Nd K x-rays measured in coincidence with the protons assign the activity to the new isotope ^{130}Pm. This is the first observation of proton emission from a promethium precursor. The measured half-life agrees well with the predicted value of 2 s [3].

A=132: ^{132}Pm with a half-life of 4 ± 2 s was previously identified by decay analysis of the Nd x-rays associated with electron capture [4]. No delayed proton branch was reported. A weak delayed proton branch was expected on the basis of the 5.6 MeV $Q_{EC}-S_p$ value, and the fact that the N = 71 isotones, ^{131}Nd ($Q_{EC}-S_p$ = 4.3 MeV) and ^{133}Sm ($Q_{EC}-S_p$ = 7.1 MeV), were known delayed proton emitters. Delayed

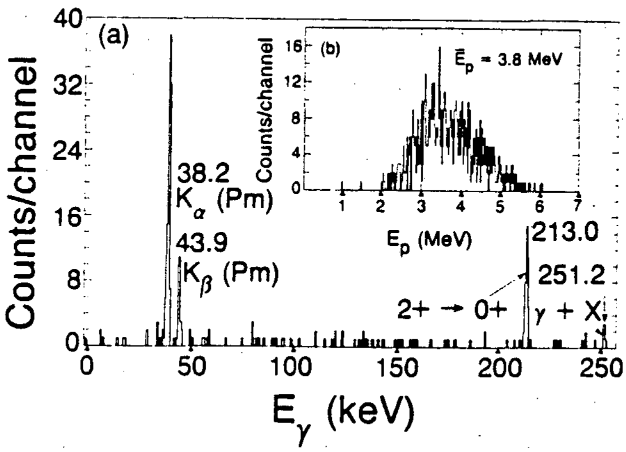

Fig. 1: Low energy photons (a.) in coincidence with beta-delayed protons (b.) from ^{133}Sm.

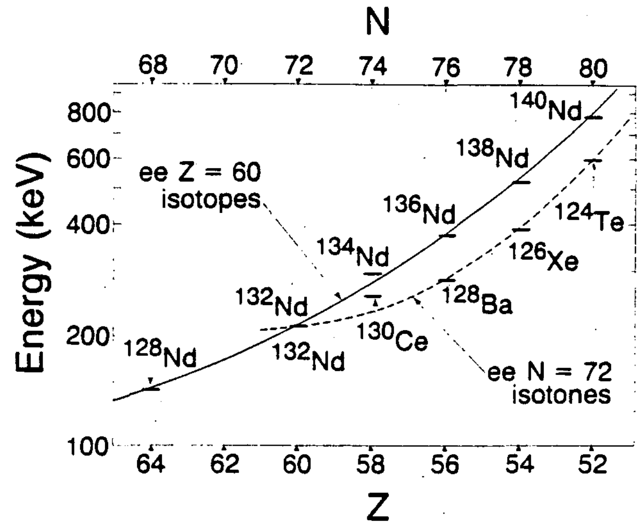

Fig. 2: Systematics for the lowest energy 2+ levels in ee Nd isotopes and ee N=72 isotones, including the latest result for ^{132}Nd. (In a recent experiment where we synthesized ^{131}Sm we have found evidence for the lowest 2+ level in ^{130}Nd at 159 keV.)

protons with a half-life of $5.0^{+0.8}_{-0.6}$ s were observed and assigned to ^{132}Pm on the basis of the Nd K x-rays in coincidence with the protons.

A=133: A β-delayed proton activity with a half-life of 3.2 ± 0.4 s was assigned to ^{133}Sm by Bogdanov et al. [4] based on systematics for delayed proton emission. We observed a strong delayed proton activity in coincidence with Pm K x-rays (fig. 1) confirming this activity as ^{133}Sm. Our half-life value of 2.8 ± 0.2 s is in reasonable agreement with the above result. A strong feeding of the lowest 2+ level in ^{132}Nd was observed in coincidence with the protons. This is the first observation of the 2+ level in ^{132}Nd. Its energy of 213.0 keV agrees well with the value expected from the systematics for this region (fig. 2). The predicted ground state spin for ^{133}Sm is 5/2+ [5]. Statistical model calculations indicate that this would result in a 12% proton decay branch to the 4+ level in ^{132}Nd. The expected 4+ to 2+ gamma transition was, however, not observed in the experiment and the question of the ground state spin and parity of ^{133}Sm, therefore, remains presently unresolved.

TABLE 1: E_{LAB} = bombarding energy; $T_{1/2}$,exp = measured half-life of the precursor; and $T_{1/2}$,g.t. = half-life of the precursor predicted from the gross theory of beta decay [3].

TABLE 1.

Isotope	Reaction	E_{LAB} (MeV)	$T_{1/2}$,exp. (s)	$T_{1/2}$,g.t. (s)
^{128}Pr	^{92}Mo(^{40}Ca,3pn)	170	$3.2^{+0.5}_{-0.4}$	9
^{129}Nd	^{92}Mo(^{40}Ca,2pn)	170	4.9±0.2	7
^{130}Pm	^{92}Mo(^{40}Ca,pn)	170	$2.2^{+0.6}_{-0.4}$	2
^{132}Pm	^{96}Ru(^{40}Ca,3pn)	175	$5.0^{+0.8}_{-0.6}$	5
^{133}Sm	^{96}Ru(^{40}Ca,2pn)	175	2.8±0.2	4

REFERENCES

1. J.M. Nitschke, Nucl. Instr. Meth. 206, 341 (1983).
2. J.M. Nitschke, M.D. Cable, and W.-D. Zeitz, Z. Phys. A 312, 256 (1983).
3. K. Takahashi, M. Yamada, and T. Kondoh, Atomic and Nucl. Data Tables 12, 101 (1973).
4. D.D. Bogdanov, A.V. Demyanov, V.A. Karnaukhov, L.A. Petrov, A. Plohocki, V.G. Subbotin, and J. Voboril, Nucl. Phys. A275, 229 (1977).
5. P.A. Seeger and W.M. Howard, Los Alamos Scientific Laboratory, Report LA-5750 (1974).

This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

TABLE 2: E_p,ave = average energy of the delayed protons; E_p,range = energy range of the delayed protons; K_α,K_β = the average K_α and K_β x-ray energies observed in coincidence with delayed protons; and GAMMA = principal gamma lines observed in coincidence with protons.

TABLE 2.

Isotope	E_p,ave. (MeV)	E_p,range (MeV)	K_α,K_β	GAMMA (keV)
^{128}Pr	3.2	1.9-5.0	34.5,38.6	---
^{129}Nd	3.7	1.8-5.6	35.5,40.9	207,400
^{130}Pm	3.9	2.1-5.8	36.7,42.3	---
^{132}Pm	3.6	2.2-5.0	36.7,42.0	---
^{133}Sm	3.8	2.0-6.0	38.2,43.9	213.0

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720