Few-valence-particle excitations around doubly magic ^{132}Sn

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Received August 6, 1996

Abstract. Prompt γ-ray cascades in neutron-rich nuclei around doubly-magic ^{132}Sn have been studied using a ^{248}Cm fission source. Yrast states located in the $N = 82$ isotones ^{134}Te and ^{135}I are interpreted as valence proton and neutron particle-hole core excitations with the help of shell model calculations employing empirical nucleon-nucleon interactions from both ^{132}Sn and ^{208}Pb regions.

PACS numbers: 21.60.Cs, 23.20.Lv, 25.85.Ca, 27.60.+j

What we know about the ^{132}Sn nucleus and its neighbors comes mainly from β^- decay studies of short-lived radionuclides produced in fission of actinides; consequently our knowledge about simple excitation modes, single particle energies, effective nucleon-nucleon interactions and other basic properties in this region is far from complete. The large multidetector γ-ray arrays, which can separate the prompt γ-ray cascades within a single fission product nucleus (of moderate yield) from the bulk of prompt γ-rays, have now opened new prospects for detailed studies of yrast excitations in ^{132}Sn and the few valence particle nuclei around it. The spectroscopy of ^{132}Sn and its neighbors should in many ways resemble that of the well studied nuclei around $Z = 82$, $N = 126$ ^{208}Pb, and comparisons of experimental data from these and other magic regions would help the development of a "universal" theoretical description of shell model properties.

The measurements reported here were performed at Eurogam II using a ^{248}Cm source which delivered $\sim$6.3x10^4 fissions/sec. Eurogam II at the time consisted of 52 escape-suppressed spectrometers incorporating 124 Ge detector elements, here augmented by four LEPS spectrometers; in total, 2x10^9 threefold or higher-fold coincidence events were recorded. The excellent quality and high selectivity of the triple coincidence γ-ray data made it possible to identify even weak transitions in the nuclei of interest extending over the $Z = 50 - 54$, $N = 80 - 84$ range. Cross coincidences observed between γ-rays from partner light and heavy fission products were often of key importance in establishing isotopic assignments for previously unknown cascades; in other cases, some overlap with the γ-rays known from β-decay provided vital first clues. The findings for only two of these nuclei - the two- and three-proton $N = 82$ isotones ^{134}Te and ^{135}I - are presented here, but results for other fission products around ^{132}Sn will also be forthcoming.

In the two-proton nucleus ^{134}Te, many members of the $\pi g_{7/2}{}^2$, $\pi g_{7/2}d_{5/2}$ and $\pi g_{7/2}h_{11/2}$ multiplets are known from ^{134}Sb β^- decay studies, especially the recent work of Omtvedt et al. [1]. The present fission product measurements identified two dominant high-energy γ-rays feeding the 1691 keV $\pi g_{7/2}{}^2$ 6^+ state in ^{134}Te, one the 2322 keV $9^- \rightarrow 6^+$ E3 transition known from β-decay [1], the other a 2866 keV γ-ray from a ^{134}Te level at 4557 keV. Gating on this 2866 keV γ-ray revealed many new ^{134}Te γ-rays, and the full $\gamma\gamma\gamma$ results established the level sequence above 4557 keV shown to the left in the ^{134}Te scheme (Fig. 1). Since the only possible two-proton state with I>9 is $(\pi h_{11/2}{}^2)$ 10^+, expected in ^{134}Te above 7 MeV, the obvious conclusion is that these new states must involve excitation of the ^{132}Sn core. We interpret them as $\pi g_{7/2}{}^2 \nu f_{7/2} h_{11/2}{}^{-1}$ states, with strong support from shell model calculations described below.

Nothing was known up to now about high-spin states in the $N = 82$ nucleus ^{135}I, but a ^{135}Te β^--decay study[2] has located an $11/2^+$ level at 1134 keV above the ^{135}I $\pi g_{7/2}$ ground state. In the present work, gates on 1134 keV γ-rays identified other strong γ-rays in ^{135}I, and the full $\gamma\gamma\gamma$ results established the ^{135}I level scheme presented in Fig. 1. Since no information about transition multipolarities was derived from the data, the spin-parity assignments and the interpretation of the ^{135}I levels below 4 MeV as $\pi g_{7/2}{}^3$, $\pi g_{7/2}{}^2 d_{5/2}$ and $\pi g_{7/2}{}^2 h_{11/2}$ states are largely based on shell model calculations for which the nucleon-nucleon interactions were taken directly from the ^{134}Te level spectrum. It is no surprise that the yrast excitations of ^{135}I are found to resemble closely those of the other three-proton nucleus ^{211}At.

The sequence of levels above 4241 keV in ^{135}I must involve core excitations, and we naturally interpret them as $\pi g_{7/2}{}^3 \nu f_{7/2} h_{11/2}{}^{-1}$ states directly related to the core-excited states in ^{134}Te. Particle-hole states of $\nu f_{7/2} h_{11/2}{}^{-1}$

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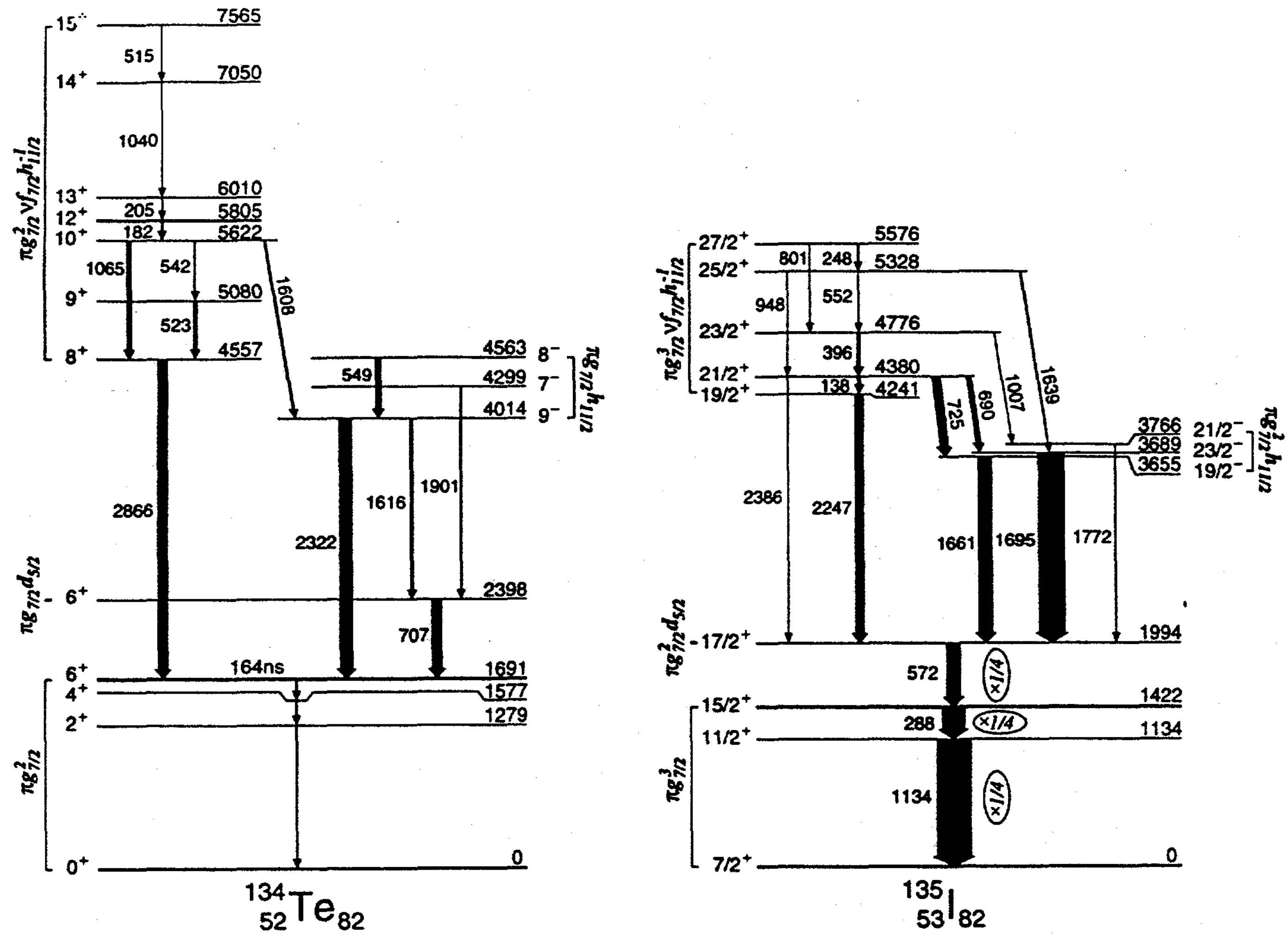

Fig. 1. The yrast level spectra established for ^{134}Te and ^{135}I. Widths of the transition arrows are proportional to the observed γ-ray intensities, except for transitions below the 164 ns isomer in ^{134}Te. Configuration assignments in both nuclei are also shown.

character with $I^{\pi}=2^{+}$ to 8^{+} are known[3] in ^{132}Sn, and their energies provided some of the two-body interactions needed for calculating $\pi g_{7/2}{}^{n}\nu f_{7/2}h_{11/2}{}^{-1}$ states. In addition $\pi g_{7/2}\nu h_{11/2}{}^{-1}$ and $\pi g_{7/2}\nu f_{7/2}$ interactions were also needed, and these had to be estimated from corresponding multiplets in ^{208}Bi and ^{210}Bi, with scaling as $A^{-1/3}$ to take account of nuclear size variation[4]. Calculations of $\pi g_{7/2}{}^{n}\nu f_{7/2}h_{11/2}{}^{-1}$ energies were performed using the OXBASH shell model code, and the results were found to be in excellent agreement with experiment for both ^{134}Te and ^{135}I, thus providing persuasive support for the proposed interpretations.

In summary, neutron-rich fission product nuclei around doubly magic ^{132}Sn have now become accessible for detailed study by prompt γ-ray measurements using multidetector arrays. Yrast excitations to above 5.5 MeV excitation energy in the two- and three-proton nuclei ^{134}Te and ^{135}I have been established and interpreted with the help of precise shell model calculations using empirical nucleon-nucleon interactions. These results open possibilities for exploring simple excitation modes in the ^{132}Sn region under conditions that are comparable with but not identical to those in the well-studied ^{208}Pb region.

Acknowledgement. This work was supported by the U.S. Department of Energy under contract nos. DE-FG02-87ER40346 and W-31-109- ENG-38, by the Science and Engineering Council of the UK under grant no. GRH 71161, and by Polish Scientific Committee grant no. 1044-PO3-96-10. The authors are indebted for the use of ^{248}Cm to the Office of Basic Energy Sciences, US Dept. of Energy through the transplutonium element production facilities at the Oak Ridge National Laboratory.

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