Spectroscopy in the Superdeformed Minimum of ^{240}Pu

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Conversion electrons from electromagnetic transitions preceeding the spontaneous fission of the 3.7 ns ^{240m}Pu fission isomer have been measured. States in the second minimum were populated by the ^{238}U(α,2n)-reaction at E_α=25 MeV. From the measurement absolute values of conversion coefficients could be determined. The electron spectrum shows a broad structure of fast E0-transitions between 625 and 650 keV, which is interpreted as the decay of the lowest β-vibrational band with a phonon energy of (770.8$\pm$1.0) keV. Together with the detailed data from a recently performed high resolution γ-spectroscopy at the MPI in Heidelberg the predominant population of negative parity states can be reported.

In the conversion electron measurement at the Munich Tandem Accelerator Laboratory the recoil shadow technique in combination with three Mini-Orange spectrometers was used. Conversion electrons from electromagnetic transitions preceeding the spontaneous fission of the ^{240m}Pu fission isomer were measured in delayed coincidence with fission fragments. By applying the recoil shadow technique, electrons caused by the 10^5 to 10^6 more intense prompt fission were suppressed. Therefore the 6.25 mm^2 ^{238}U-target of 30 $\mu g/cm^2$, evaporated onto a 10 $\mu g/cm^2$ C backing was placed in the 4 mm diameter hole of an 450 mm^2 annular semiconductor detector. Prompt fission occured at the target position in the shadow of the sensitive area of the annular detector, whereas the ^{240}Pu recoil nuclei in the 3.7 ns isomeric state decayed in flight in front of the detector. Thus, only fragments from isomeric fission and not from prompt fission were detected. The conversion electrons were measured with three cooled 300 mm^2 and 3mm thick Si(Li)-detectors with Mini-Orange-filters in front of them. Each of the Mini-Orange-filters consisted of 6 wedge-shaped $Nd_2Fe_{14}B$ permanent magnets arranged symmetrically around a 20 mm long cylindric Pb absorber of 6 mm radius. A homogenous toroidal magnetic field of 90 $\pm$ 5 mT in the inner 30 mm radius of the Mini-Oranges provided a transmission efficiency of 5.4 % at an electron energy of 626 keV and a target to Mini-Orange and Mini-Orange to detector distance of 55 mm and 60mm, respectively. With this setup $1.2 * 10^5$ fragments from isomeric fissions and 1260 coincidence events between delayed fission and conversion electrons were measured. The recorded conversion electron spectrum is shown in the lower part of fig.1. Together with the unambiguous separation between delayed and prompt fission events, the setting of a prompt time gate between electrons and fission fragments and the subtraction of random coincidences assures for the removal of any background in the conversion electron spectrum. The spectrum is shifted by the electron binding energy E_K=121.8 keV of ^{240}Pu with respect to the γ-ray spectrum of transitions in the second minimum of ^{240}Pu shown in the upper part of fig.1. The γ-ray spectrum was recently measured at the Heidelberg MPI Tandem accelerator by D. Pansegrau et al. [1], where 6 EUROBALL CLUSTER detectors surrounding a PPAC array were employed to detect γ-rays in delayed coincidence with fission fragments from the decay of the isomeric state of ^{240}Pu. Reaction channel and projectile energy were identical in the electron and γ-ray experiments.

Fig.2 shows the level scheme of ^{240}Pu in the second well, obtained from the combined analysis of both experiments. The ground state rotational band with its rigid rotor moment of inertia was observed already 1972 by H.J. Specht et al. [2]. Conversion electron spectroscopy at higher energies enabled now the detection of strong E0-decays from the J$\rightarrow$J$_g$ transitions of a β-band with a band-head energy of 770.8 keV. The vibrational energy of $\hbar\omega_{\rm II}$ =770.8 keV is smaller than the phonon energy $\hbar\omega_{\rm I}$ =1098 keV in the first minimum and results together with the theoretically calculated variation of the mass parameter [4] in an increase of the B(E2)-strength by 2.4. This increase shows, that similar to the situation in ^{236,238}U [5], the β-vibration in the second minimum is more collective than in the first well. The β-band is the only band in the second well that exhibits a considerable variation of the moment of inertia with the rotational frequency, with a value close to the rigid rotor moment of inertia at low spins, while for higher spins this value gradually approaches the one of the ground state band.

For the strong transition at 786.1 keV an E1 conversion coefficient of $\alpha_K = (6.3 \pm 1.7) * 10^{-3}$ was measured. This allowed to deduce the spin and parity of the K$^\pi$ = 2$^-$-band with a band head energy of 806.2 keV. It can be interpreted as a K= 2$^-$ octupole band. From the branching ratio of the decay of the 3$^-$-state of this band to the ground state band via E1 interband-transitions a lifetime for the band head of $\sim$ 150 ps can be estimated, resulting in a hinderance of the E1-transition with ΔK=2 in the expected range of 10^5.

From a combined analysis of prompt fission probabilities and photofission yields a K$^\pi$ = 0$^-$ octupole vibrational band is expected at 750$\pm$200 keV [3]. Checking for the very few cases where two rather strong transitions from the γ-ray spectrum fulfill the Ritz combination principle, we propose (from the relation 251.5 keV + 554.7 keV = 806.2 keV) a new band head at an energy of 554.7 keV. Furthermore, the 534.6 keV transition may be assigned to the decay of the 554.7 keV level to the 2$^+$ state of the ground state band. An additional summing relation (216.5 keV + 569.6 keV +20.1 keV= 806.2 keV) yields a rotational level at 589.7 keV on top of the 554.7 keV level. From intensities and branching ratios of the deexcitation of the c-band it can be deduced that a major fraction of the 554.7 keV and 569.6 keV transitions does not belong to the c-band decay and therefore it is assigned to the decay of the oc-