Determination of Auger electron spectra from the ^{140}Nd and ^{111}In decays

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Sources preparation

^{140}Nd was produced by the spallation of tantalum irradiation with 660 MeV protons at the phasatron of the JINR, Dubna. A standard chemical procedure [1] was employed to extract the isotope from the irradiated target. ^{111}In was produced in the reaction ^{109}Ag(α,2n)^{111}In by irradiation of a natural Ag with 30 MeV α-particles at the accelerator U-200 of the JINR, Dubna. The cation-exchange chromatographic separation [2] was employed to extract the isotope from the irradiated target. Sources of ^{140}Nd and ^{111}In for electron spectrum measurements were prepared by modified LB method [3], developed for preparation of small size radioactive sources as monomolecular layers.

Spectrum measurements

Auger electron spectra of ^{111}Cd and ^{140}Pr + ^{140}Ce generated in EC-decays of ^{111}In and ^{140}Nd, respectively, were measured using a combined electrostatic spectrometer [4]. A region of L-Auger electrons of ^{111}Cd was scanned with the instrumental resolution of 4 eV and those of ^{140}Pr + ^{140}Ce with the instrumental resolution of 7 eV. Regions of K-Auger groups of ^{111}Cd and ^{140}Pr + ^{140}Ce were taken with the 35 eV instrumental resolution.

A calibration of the absolute energy scale of the spectrometer was carried out with suitable conversion electron lines of nuclear transitions in ^{169}Tm resulting from the EC-decay of ^{169}Yb. Effective transmissions at different instrumental resolutions applied were estimated from measurements of the narrow K-conversion electron line of the 14.4 keV transition in ^{57}Fe (from the EC-decay of ^{57}Co).

In order of determine absolute activities of the ^{111}In and ^{140}Nd samples, the 171.20 keV and 245.35 keV γ-lines emitted in the EC-decay of ^{111}In and the 511 keV annihilation peak of the β^+ branch of the ^{140}Pr decay were considered.

Information on the transmission curve of the electron spectrometer in the very low energy region from 1 to 20 keV for the instrumental resolution of 35 eV was derived both from ^{241}Pu β^- spectrum measurements and extrapolated to higher energies from intensities of conversion electron lines of ^{169}Tm taken with the instrumental resolution of 4 and 7 eV [5]. Additional measurements without any source in the spectrometer were performed for estimation of background level.

Electron spectra evaluation

After the background was subtracted from the measured spectra, correction was made for both the half-lives of ^{140}Nd ($T_{1/2}$ = 3.73 d) and ^{111}In ($T_{1/2}$ = 2.83 d) and the spectrometer transmission changing. The measured spectra with corrections are illustrated in figs. 1, 2.

Calculations: The intensity of the K-Auger group of ^{111}Cd relative to that of ^{140}Pr+^{140}Ce was determined to be 1.52. For EC-decays of ^{111}In, ^{140}Nd and ^{140}Pr, the L + M to K-capture probability ratios were taken from [6] and K-fluorescence yields for Z = 48, 58 and 59 from [7]. In the case of ^{111}Cd, probabilities for K-conversion of the dominant nuclear transitions were also taken into account. A ratio of the EC to β^+ branches of the ^{140}Pr decay was taken from [8].

K-Auger electron groups: We have found relative intensities of the K-Auger groups arising from the decays of ^{140}Nd and ^{111}In are in reasonable agreement with the calculated ones: $^{111}In_{K\text{-}Auger}$ / $^{140}Nd_{K\text{-}Auger}$ = $1.47 \pm 0.01_{stat.} \pm 0.12_{syst.}$.

Since intensity of the KXY-Auger group relative to that of the KLL + KLX groups is insignificant it was not taken into account. Systematic errors may arise from not full (or exact) information about: 1) scattering of electrons in the spectrometer, 2) the transmission dependence, 3) a possible time dependence of the electron detector efficiency (channel electron multiplier), 4) the absolute activities of the measured sources, 5) shapes of low energy tails of the measured spectrum lines.

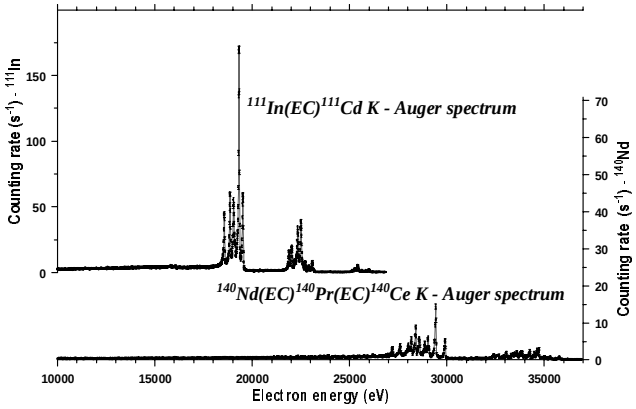

Fig. 1. K-Auger spectra of ^{111}Cd and ^{140}Pr+^{140}Ce measured at the instrumental resolution of 35 eV and an 10 eV step size. The spectra were corrected for both the half-lives and the spectrometer transmission changing and are normalized to the same absolute activity.

L-Auger electron groups: The ratio $^{111}In_{L\text{-}Auger}$ / $^{140}Nd_{L\text{-}Auger}$ = $1.05 \pm 0.01_{stat.} \pm 0.40_{syst.}$ was determined from the measured spectra. Since the L-Auger energy region of 2.8 – 7 keV of ^{140}Pr+^{140}Ce is more relevant from the point of view of possible medical applications, we have also determined the electron intensity ratio particularly for this region as $^{111}In_{K\text{-}Auger\ [2.8\text{-}7\ keV]}$ / $^{140}Nd_{K\text{-}Auger}$ = $0.24 \pm 0.001_{stat.} \pm 0.10_{syst.}$.

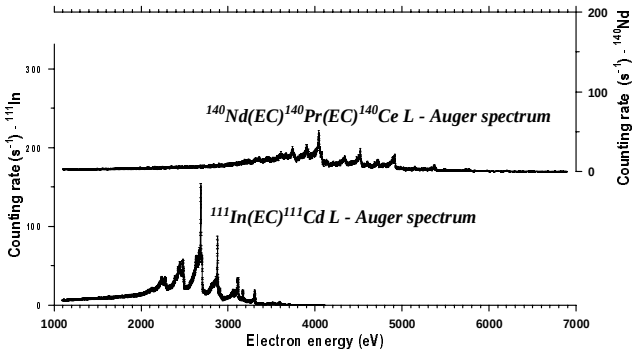

Fig. 2. L-Auger spectra of ^{111}Cd measured at the instrumental resolution of 4 eV and the 1 eV step size and those of ^{140}Pr + ^{140}Ce measured at the instrumental resolution of 7 eV and the 1 eV step size. The spectrum was corrected for both the half-lives and the spectrometer transmission changing, and are normalized to the same absolute activity and a same effective transmission.

The systematic errors arise from not well known shapes of low energy tails of electron lines which depend strongly on thickness and roughness of a source.

[1] A Kovalík et al., J Electron Spectrosc Relat Phenom, 107 (2000) 239-252. [2] DV Filossofov et al., Preprint of JINR 6-99-282, Dubna, 1999. [3] A Kovalík et al., J Electron Spectrosc Relat Phenom, 105 (1999) 219-229. [4] Ch Briançon et al., Nucl Instrum Methods 221 (1984) 547. [5] VM Gorozhankin et al., J Phys G: Nucl Part Phys 22 (1996) 377-386. [6] BS Dzhelepov et al., Beta processy, Nauka, Leningrad, 1972 (in russian). [7] CM Lederer and VS Shirley, Tables of Isotopes, 7th ed., Wiley, New York, 1978, Appendix 3. [8] CM Lederer and VS Shirley, tables of Isotopes, 7th ed., Wiley, New York, 1978, 742.