Depopulation of the J=9$^-$ Isomer in ^{180m}Ta by Photoactivation ◊

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1. Introduction

Over the years many attempts have been made to find a plausible production mechanism for nature's rarest isotope and only naturally-occuring isomer, the odd-odd nucleus ^{180}Ta. ^{180}Ta is stable in an excited state, an isomer with a halflife of $T_{1/2}$ >= $1.2 \cdot 10^{15}$ y while its ground state decays with a halflife of 8.15 h. The standard s- ,r- ans p-processes all fail to quantitatively account for the observed abundance ^{180}Ta/^{181}Ta = 0.012 %.

Regardless of how ^{180}Ta is actually produced in stars, the question remains whether it can survive in the hot, dense stellar environment. At the temperatures appropriate to the s- and r-processes there is an enormous flux of high energy photons present. Such photons could excite ^{180m}Ta up to a higher-lying level of intermediate spin which subsequently decays through a γ-cascade to the ^{180}Ta ground state. This would drastically reduce the amount of ^{180m}Ta that would emerge from the stellar environment. The question of whether or not this process actually happens in nature depends critically on the excitation energy and γ-decay modes of levels in ^{180}Ta.

The photoactivation process has been the subject of several experimental investigations using real photons (bremsstrahlung) [1] or virtual photons in Coulomb-excitation experiments [2,3].

2. Experimental setup

For a refined investigation of the ^{180m}Ta (γ, γ') ^{180}Ta reaction at the Stuttgart photon scattering facility [4] a new setup for photon activation was developed, which is shown schematically in fig. 1. The main part is a target feeder which transports the activation target safely from outside the shielding into the photon beam. A distance of only 92 mm between the activation target and the converter target ensures maximum photon flux.

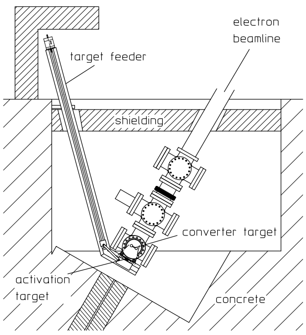

Fig. 1: Schematical drawing of the irradiation facility.

The composition of the activation targets is discussed in more detail in [5].

After passing the activation target the photon beam enters a neighbouring experimental hall trough a 1 m lead collimator. Here two setups are used to determine the photon flux and the endpoint energy of the bremsstrahl.

3. First experimental results

An indicator for the depopulation of the isomeric state is the observation of the ^{180m}Ta ground state decay to ^{180}Hf (86%) and ^{180}W (14%). It can be identified by the 93.3 keV $2^+ \rightarrow 0^+$ transition in ^{180}Hf and by Hf X-rays. Fig. 2 shows two examples of low-energy photon spectra (nuclear γ-transitions and characteristic X-rays) of activated Ta-samples, taken in December 1997 with enriched (5.6%) and natural targets. Both spectra are dominated by the well resolved $K_{\alpha 1}$ and $K_{\alpha 2}$ lines of Hf. The corresponding $K_{\beta 1}$ and $K_{\beta 2}$ are also visible. In the spectrum of the enriched sample (upper panel) even the $2^+ \rightarrow 0^+$ transition in ^{180}W is observed.

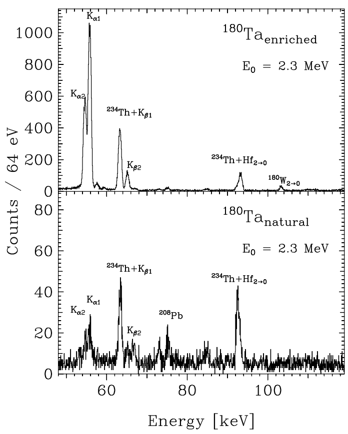

Fig. 2: Low-energy γ- and X-ray spectra of photo-activated enriched (upper panel) and natural (lower panel) Ta-target.The bremstrahlung endpoint energy for both targets was $E_0 = 2.3$ MeV. Note that the scales already differ by a factor of 12.

Systematic measurements were performed with bremsstrahlung endpoint energies in the range of E_0=1.0-3.1 MeV. Ground-state decay could be observed for natural targets down to 1.7 MeV and for the enriched target down to 1.2 MeV. The sensitivity of this study was roughly a factor 1000 higher than in previous experiments [1] due to the enrichment of the sample and to the high photon fluxes at the Stuttgart facility. A detailed analysis of the data is in progress.

References

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