DEPOPULATION OF THE $K^{\pi} = 9^{-}$ ISOMER IN ^{180}Ta via COULOMB EXCITATION*

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The depopulation of ^{180m}Ta by Coulomb excitation was investigated. The recoiling tantalum ions from bombardments with ^{36}S and with ^{64}Ni were collected in catcher foils surrounding the beam. The out-of-beam identification of the 8h decay of ^{180gs}Ta in these foils leads to the existence of a mediating state at about 1.3 MeV excited from ^{180m}Ta by an E3 transition of the order of several Weisskopf units.

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1. The nucleus ^{180}Ta

Only 0.012% of natural Tantalum consists of ^{180}Ta, while 99.988% is ^{181}Ta. The extremely rare isotope ^{180}Ta survives in nature in an $I^{\pi} = 9^{-}$ isomer (^{180m}Ta) at $E^{*} = 75.3$ keV. This isomer has a half-life of $T_{1/2} > 1.2 \times 10^{15} y$. The $I^{\pi} = 1^{+}$ ground-state (^{180gs}Ta) is unstable and decays with $T_{1/2} = 8.15$ h either by electron capture to ^{180}Hf or by β^{-} to

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^{180}W. The direct decay of the $K^\pi = 9^-$ isomer to the $\mathrm{K}^\pi = 1^+$ ground-state is highly K-forbidden. The characteristics of the ground-state decay of $^{180\mathrm{gs}}$Ta are the Hf $K_{\alpha,\beta}$ X-rays (72 X-rays per 100 decays), the $2^+ \to 0^+$ E2 transition in ^{180}Hf (5 gammas per 100 decays) and the $2^+ \to 0^+$ E2 transition in ^{180}W (0.7 gammas per 100 decays). The observation of these transitions would indicate the depopulation of the 9^- isomer to the ground-state (see Fig. 1).

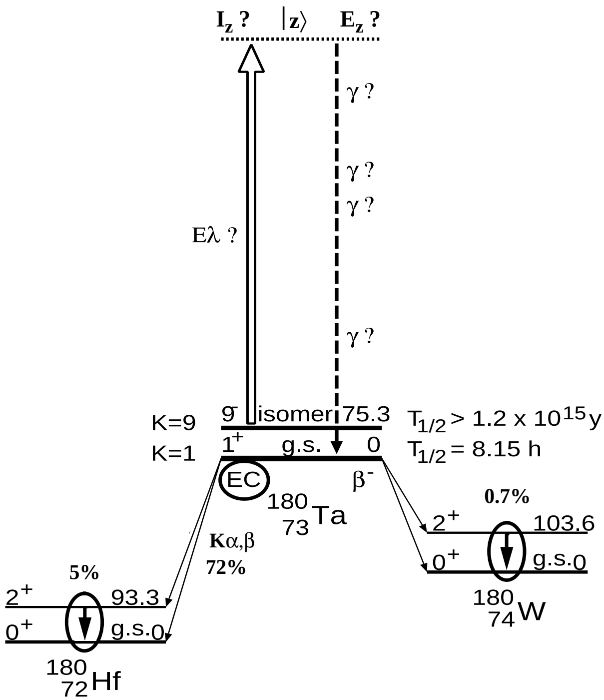

Fig. 1. Depopulation of the $K^\pi = 9^-$ isomer via an intermediate state $|z\rangle$ to the $K^\pi = 1^+$ ground-state.

2. Astrophysical aspects

The synthesis and the survival of $^{180\mathrm{m}}$Ta during the nucleosynthesis is still unclear. $^{180\mathrm{m}}$Ta is shielded by ^{180}Hf from the r-process path (see Fig. 2). In an s-process scenario a large number of Planck-distributed photons can be expected. These photons can excite intermediate states $|z\rangle$ in ^{180}Ta, which may partly decay to the unstable ground-state. Calculations show that intermediate states below 1 MeV would destroy $^{180\mathrm{m}}$Ta while it is being synthesized. Intermediate states in ^{180}Ta below 1 MeV therefore exclude a s-process synthesis of $^{180\mathrm{m}}$Ta.

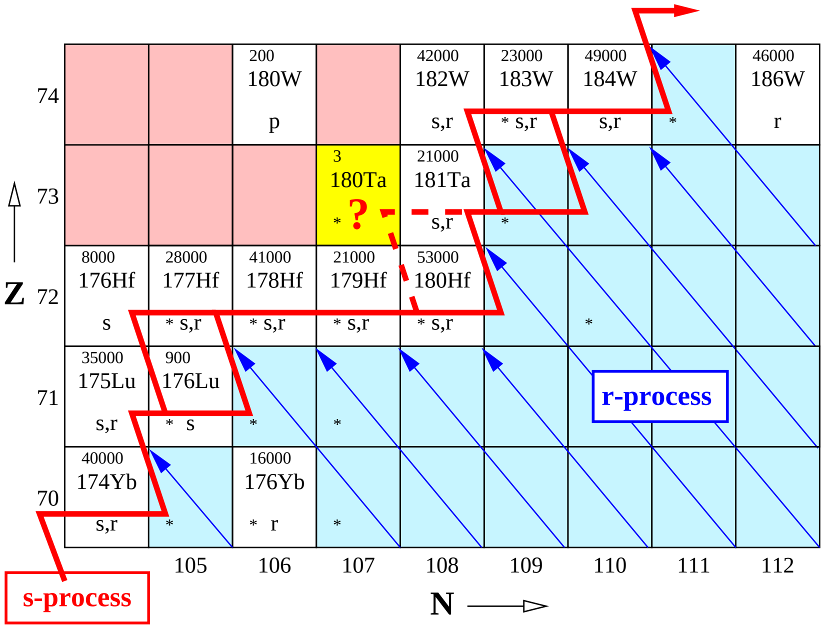

Fig. 2. s- and r-process paths in the region of $^{180\mathrm{m}}$Ta

3. Activation experiments

During the last few years many different types of experiments were performed to find intermediate states coupling the isomer and the ground-state in ^{180}Ta. Coulomb excitation (virtual photons) [1] and photo-excitation (real photons) [2] activation experiments turned out to be most successful in finding these states.

In our activation experiments we bombarded enriched $^{180\mathrm{m}}$Ta targets with ^{36}S (65–125 MeV) and ^{64}Ni (130 and 150 MeV). All particle energies were well below the Coulomb barrier. Four PIN-diodes and a current integrator were used for a continuos monitoring of the beam geometry and current. The scattered Ta-recoils were caught in thin, a few μm thick, plastic foils. In an off-beam measurement these foils were put between the end-caps of two planar Ge-detectors to obtain a high γ-detection efficiency. To reduce background radiation, the two Ge-detectors were mounted in a high-purity lead chamber with an inner compartment made of electrolyte copper. With this setup the characteristic γ-rays and X-rays of the $^{180\mathrm{gs}}$Ta ground-state decay could be observed for all beam energies (see Fig. 3).

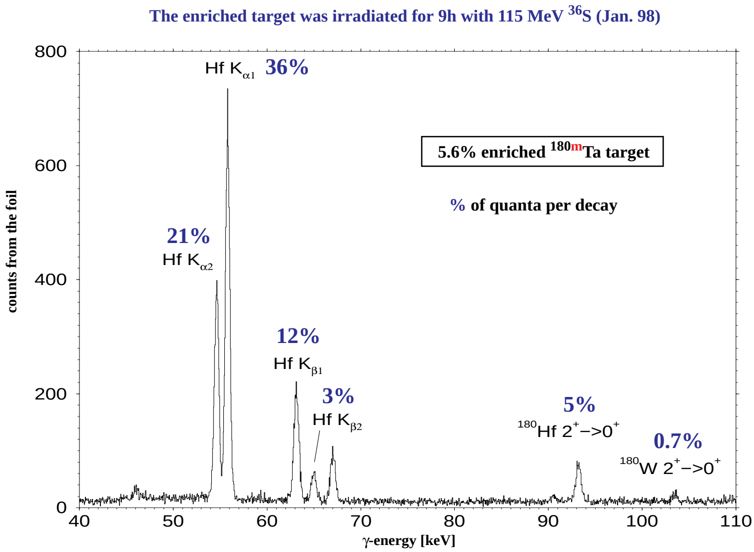

Fig. 3. Catcher-foil spectrum showing the ground-state decay of ^{180gs}Ta

4. Experimental results and conclusions

From a comparison of the experimental excitation function with Coulomb excitation calculations we can estimate the energy of the intermediate state. The calculations were done using the computer programs GOSIA [3] and COULEX [4]. To get information about the multipolarity of the excitation we cut the catcher-foils in different slices to measure the angular distribution of the ^{180gs}Ta-recoils. The best fit to the experimental data is obtained assuming an E3-excitation to an intermediate state at about 1.3 MeV. For the B(E3)-value we obtained several W.u. Assuming an E3-excitation, the energy of this intermediate state is probably too high to exclude a s-process production of ^{180m}Ta.

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