Depopulation of the $K^\pi = 9^-$ Isomer in ^{180}Ta via Coulomb Excitation ◇

M. Loewe, J. Besserer, J. de Boer, A.I. Levon[a], H. J. Maier, M. Würkner, P. v. Neumann-Cosel[b], A. Richter[b], C. Schlegel[c], J. Srebrny[d], T. Czosnyka[e], J. Iwanicki[e], P. J. Napiorkowski[e], P. Alexa[f], S. A. Karamian[g], and G. Sletten[h]

[b] Technische Universität Darmstadt, Germany [c] Gesellschaft für Schwerionenforschung (GSI), Germany
[d] Nuclear Physics Division, Warsaw University, Poland [e] Heavy Ion Laboratory, Warsaw University, Poland
[a] Institute for Nuclear Research, Ukraine
[f] Dept. of Phys. and Measurement, Inst. of Chem. Technology, Czech Republic [g] FLNR, JINR, Dubna, Russia
[h] The Niels Bohr Institute, Tandem Accelerator Laboratory, Denmark

1. The nucleus ^{180}Ta

Only 0.012% of natural Tantalum consists of ^{180}Ta, while 99.988% is ^{181}Ta. The extremly rare isotope ^{180}Ta survives in nature in an excited-state isomer (K^π=9^-, E^*=75.3keV, $T_{1/2}$>1.2x10^{15}y). The ground state is unstable and decays with a halflife of 8.1h either by electron capture to ^{180}Hf or by β^- to ^{180}W. The direct decay of the K^π=9^- isomer to the K^π=1^+ ground state is highly K-forbidden. The characteristics of the ground state decay of ^{180}Ta are the Hf K X-rays (72 X-rays per 100 decays), the $2^+ \rightarrow 0^+$ E2 transition in ^{180}Hf (5 gammas per 100 decays) and the $2^+ \rightarrow 0^+$ E2 transition in ^{180}W (0.74 gammas per 100 decays). The observation of these gammas would indicate the depopulation of the 9^- isomer to the ground state (see fig. 1).

2. Astrophysical aspects

The production and the survival of the ^{180}Ta 9^- isomer during the nucleosynthesis is still unknown. Should the isomer be exposed to an intense photon bath under stellar s-process conditions, it might be depopulated to the ground state through intermediate states. Therefore low-lying intermediate states, yet unknown, connecting the isomer to the ground state would hinder a s-process production of ^{180}Ta. To find these intermediate states, several photoexcitation (real photons) [1,2] and Coulomb excitation (virtual photons) [3–6] experiments were carried out.

3. Experimental procedure

In our activation experiments we bombarded two Tantalum oxide targets: one 5.6% enriched in ^{180}Ta and for comparison a similar, but natural target with ^{36}S and ^{64}Ni. All beam energies were well below the Coulomb barrier (^{36}S: from 65MeV to 115MeV; ^{64}Ni: 130MeV and 150MeV) to minimize possible transfer reactions on ^{181}Ta. Four PIN-diodes and a current integrator were used for a continous monitoring of the beam geometry and current. The scattered Ta-recoils were catched in thin plastic foils mounted in an aluminium cylinder around the beam axis. After typical irradiation times of 9h these foils were placed in front of planar Ge-detectors to look for the characteristic gammas of the ^{180}Ta ground state decay. To find the multipolarity of a possible Coulomb excitation of intermediate states connecting the isomer to the ground state, the catcher foils were cut in different slices corresponding to different recoil scattering angles. To reduce background radiation, the Ge-detectors were mounted in a high purity lead chamber with an inner compartment made of electrolyte copper.

4. Experimental results

We were able to observe the ground state decay of ^{180}Ta for all used beam energies. It is surprising to get only 5 to 10 times less ^{180}Ta nuclei in ground state when using natural targets, although the amount of ^{180}Ta nuclei in these targets is 5.6%/0.012% $\cong$ 470 times smaller compared to the enriched targets. Besides the depopulation of the isomer to the ground state via Coulomb excitation there might be a different effect connected to ^{181}Ta producing ^{180}Ta in its ground state, too. The detailed analysis of the comprehensive new data material is in progress.

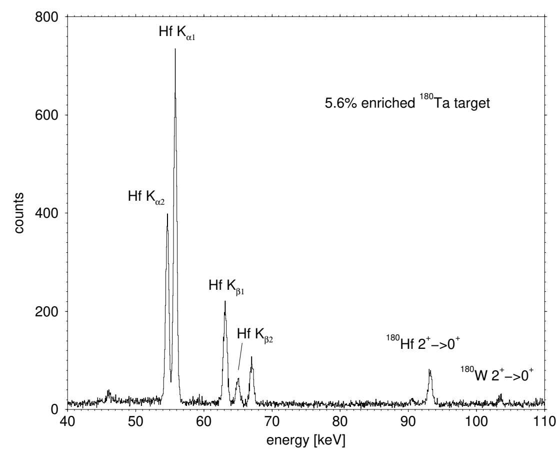

Fig. 1: Gamma spectrum of the catcher foil accumulated for 10h. The enriched target was irradiated for 9h with 115MeV ^{36}S ions. The spectrum clearly shows the ground state decay of ^{180}Ta.

References

[1] C.B. Collinset *et al.*, Phys. Rev. **C42** (1990) R1813
[2] J. Besserer *et al.*, this report p. 22
[3] C. Schlegel *et al.*, Phys. Rev. **C50** (1994) 2198
[4] M. Loewe *et al.*, Z. Phys. **A356** (1996) 9
[5] P. v. Neumann-Cosel *et al.*, Nucl. Phys. **A621** (1997) 278c
[6] M. Schumann *et al.*, Nucl. Phys. **A621** (1997) 274c

◇ This work was jointly funded by the following agencies: Tandem-Accelerator Laboratory, LMU and TUM, Munich; DFG, grant Bo 1109/1-5; Volkswagen-Stiftung, grant I/70 407; WTZ grant UKR-036-96.