Cross section measurements on the radioactive p-process isotope ^{154}Dy

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The nucleosynthesis of elements beyond iron is dominated by the *s* and *r* processes. However, 35 stable isotopes between ^{74}Se and ^{196}Hg on the proton-rich side cannot be made by neutron capture. These isotopes are thought to be produced by photodisintegration reactions on existing seed nuclei in the so-called "*p* process". So far most of the *p*-process reactions are not yet accessible by experimental techniques are inferred from statistical Hauser-Feshbach model calculations. The parametrization of these models has to be constrained by measurements on stable proton-rich nuclei. A recent suggestion for experiments on isotopes, which exhibit an increased sensitivity to reaction rate uncertainties within the *p*-process flow [1], showed a high priority for the ^{154}Dy(α,γ)^{158}Er reaction. We present here the predicted yields for activation measurements on the radioactive *p*-process nuclide ^{154}Dy in the relevant energy range (*T*= 2-3 GK for proton and α capture, and *T* = 0.3 GK for the neutron captures during freeze out).

The radioactive ^{154}Dy was isolated together with other radio-lanthanides from a massive 195 g Ta rod used as neutron converter at the CERN/ISOLDE facility, which had received a total dose of 2.5*10^{18} protons of 1 – 1.4 GeV. After a cooling period of 8 months, several radio-lanthanide fractions were obtained with a sophisticated radiochemical separation procedure in high purity. The respective Dy fraction with the long-lived radioactive ^{154}Dy (T½ = 3*10^{6} y) is of special astrophysical interest as a target for cross section measurements.

The sample was prepared from the respective Dy fraction dissolved in α-HIB of pH 4.6. For the electrolytic deposition on a Ta backing, the organic solution was removed and exchanged with an electrolytic solution (aqueus NH_4Cl/HCl solution of pH 1.8). The deposition as $Dy(OH)_3$ on a Ta backing was carried out at *U*=15 V in an electrolytic cell [2] for 1 h with a reaction yield of ≥ 95%.

The amount of ^{154}Dy was measured via α-spectrometry (E_α= 2.87 MeV) and yielded 87.9 Bq, corresponding to 1.2*10^{16} atoms or 3 µg ^{154}Dy. The largest detectable contamination originates from ^{159}Dy (T½ = 144.4 d) with ~2.2*10^{12} atoms (0.6 ng).

The sample will be first used for measuring the (*n*,γ) rate, before the α-induced cross section is determined in a second step. This channel needs to be checked experimentally rather than the proton-induced reactions.

Neutron capture rate: The Hauser-Feshbach codes NON-SMOKER [3] and MOST [4] predict Maxwellian averaged cross sections of 1342 mb and 1467 mb, respectively, at *kT*= 30 keV. Using the ^{7}Li(*p*,*n*)^{7}Be source at the Karlsruhe Van de Graaff accelerator to simulate a quasi-stellar neutron spectrum [5] with a total neutron flux of 1.3*10^{14} *n* / 24 h, the expected activity of ^{155}Dy (T½ = 10 h) is 196 Bq, which can be easily counted in the close geometry of a HPGe clover setup.

Proton and α capture rates: The predicted cross sections for proton and alpha capture in the astrophysical relevant Gamow windows (E_p= 2.3 – 5.4 MeV and E_α= 6.5 – 12.3 MeV, corresponding to *T* = 2-3 GK) are shown in Fig. 1. Reasonable statistics (assuming beam currents of 5 µA) for the proton capture are expected beyond E_p= 3 MeV, whereas the α capture measurement could only be performed at the upper limit of the Gamow window at $E_\alpha \geq$ 12 MeV.

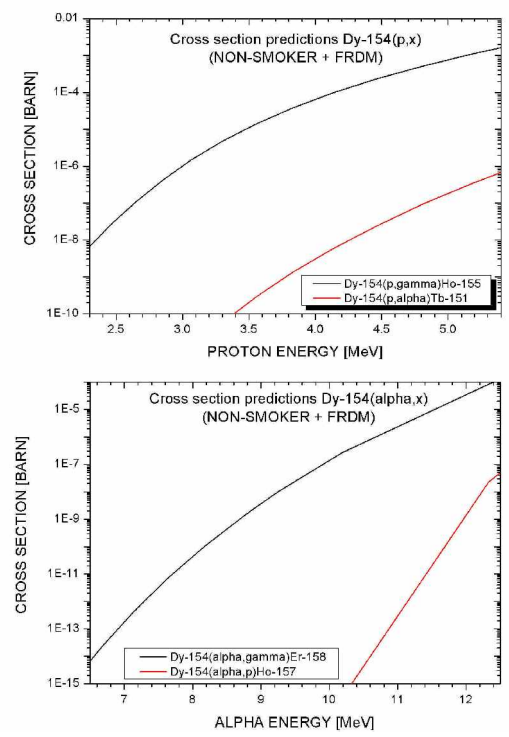

Fig. 1: Predicted cross sections for (top) proton-induced reactions and (bottom) α-induced reactions on ^{154}Dy within the Gamow window of the *p* process.

References:

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