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Determination of the (n,γ) reaction rate of unstable ^{185}W in the astrophysical s-process via its inverse reaction

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The (γ,n) reaction rate of ^{186}W was measured in order to deduce the (n,γ) reaction rate of ^{185}W, an important branching point in the astrophysical s-process. The theoretical predictions have been confirmed and the error range was slightly decreased. The derived Maxwellian averaged cross section (MACS) at 30 keV is (687 $\pm$ 110) mb.

1. Introduction

The ratio of the (n,γ) reaction rate and β-decay rate of branching points in the astrophysical s-process is the crucial factor for the calculated ratios of isotope abundances. But the direct measurement of the (n,γ) reaction rate is almost impossible because of the β-instability of the branching point nuclei. We have therefore followed the idea to learn more about the MACS by observing the inverse reaction rate and initially tested our procedure at the branching point ^{185}W.

2. Experimental Set-up and Difficulties

A naturally composed target of tungsten (fraction of ^{186}W: 28.6%) was activated using a bremsstrahlung spectrum with a maximum energy of E_{max} = 8775 keV which was produced at the real photon set-up at the superconducting linear electron accelerator S–DALINAC [1,2]. The target is usually mounted behind a collimator at a distance of about 150 cm behind the radiator target. At this position the spectral composition of the beam is known in detail [3]. However, this time we had to use the highest flux available and hence, put the target directly behind the radiator target. To avoid systematic uncertainties a relative measurement using gold as a standard was carried out [4].

A high yield of ^{185}W became necessary because of its relatively long half-life $T_{1/2}$ = (75.1 ± 0.3) d and the weak γ-ray branch in the β-decay of ^{185}W to ^{185}Re of only $(1.92 \pm 0.07) \times 10^{-4}$ [5]. Aside from these properties the low γ-energy of E_γ = 125.4 keV admits

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self-absorption in the target so that the amount of target material was limited. The γ-rays coming from the decay of the activated target were measured using a well-shielded high-purity germanium (HPGe) detector with a relative efficiency of 30% and an energy resolution of 2 keV (at 1332.5 keV).

Despite all the limiting characteristics of the decay of ^{185}W the 125.4 keV γ-line could clearly be identified and analyzed with negligible statistical errors. As an example the upper part of Fig. 1 shows a typical γ-ray spectrum of the activated tungsten target that has been measured for twelve hours. In the lower part a spectrum of the gold standard with its significant γ-lines at 333.03, 355.73, and 426.10 keV is shown. Note that the measuring time of this spectrum was only about 2.5 hours.

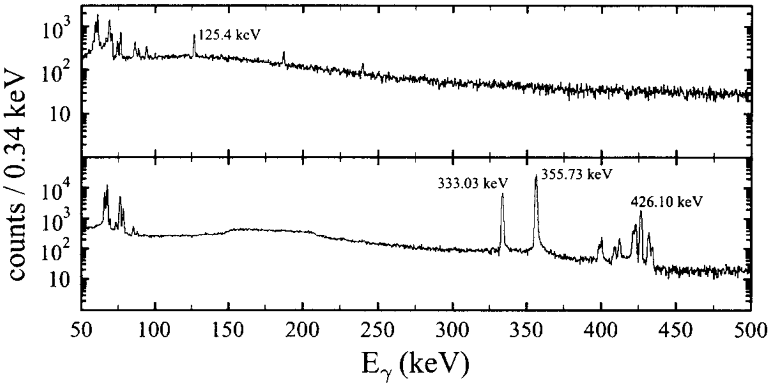

Figure 1. Typical γ-ray spectra of the activated tungsten (upper part) and gold (lower part, standard) targets. Despite its unpleasant properties the 125.4 keV line from the decay ^{185}W $\rightarrow$ ^{185}Re can clearly be identified after a measuring time of twelve hours. In contrast, the significant γ-lines from ^{196}Au $\rightarrow$ ^{196}Pt,Hg (333.03, 355.73, and 426.10 keV) have already much better statistics after 2.5 hours.

To assure that we have really observed the 125 keV line from ^{185}W the decay of the activity was followed over more than one half-life. The analysis of the decay curve shown in Fig. 2 leads to a half-life of $T_{1/2} = (76.6 \pm 1.5)$ d which agrees with the adopted value of $T_{1/2} = (75.1 \pm 0.3)$ d within the uncertainties.

3. Results and Conclusions

Using the $(\gamma$,n) cross section determined in [6,7] for the gold standard and a theoretical assumption of the energy dependence of the tungsten cross section $\sigma_{\text{theo}}(E)$ it is possible to normalize the calculations to our data by a factor f because of the experimental yield being proportional to the energy-integrated cross-section.

The corrected theoretical prediction $f\cdot\sigma_{\text{theo}}(E)$ can be used to calculate the temperature-dependent reaction rate $\lambda(T)$ of ^{186}W$(\gamma$,n$)^{185}$W up to high temperatures. E.g., at a

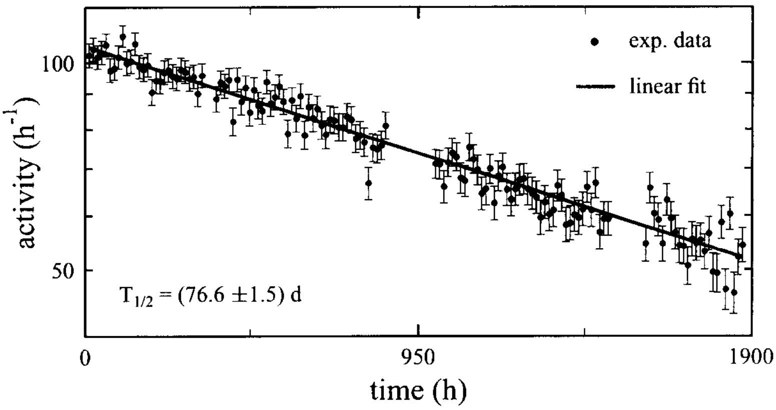

Figure 2. Decay of the activity at 125.4 keV in the tungsten spectra. The half-life was derived with a least-mean square fit to the data points. Its value of $T_{1/2} = (76.6 \pm 1.5)$ d agrees with the adopted value within the errors.

typical temperature of the p-process of $T_9 = 2.5$ the ground state reaction rate $\lambda_{g.s.} = (314 \pm 44)$ s^{-1} with the error resulting from experimental uncertainties of the correction factor f (compare [3,7,8]).

We assume as a simplification that the normalization factor f is also valid for the MACS of the reaction ^{185}W(n,γ)^{186}W. At 30 keV a value of (687 ± 110) mb is derived which is in good agreement with the former theoretical predictions but has a smaller error spread and is based on experimental data [4].

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