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Measurement of $^{183}\text{W}(n, n'\gamma)$ and $(n, 2n\gamma)$ cross-sections (preliminary)

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Abstract. The necessary improvement of evaluated nuclear databases for application will be achieved with improvement of models and new, precise data. In particular, the effect of inelastic neutrons scattering can be of importance for reactors. In order to test the models, we performed measurement of $(n, n'\gamma)$ and $(n, 2n\gamma)$ cross-sections on ^{183}W . These data will help constrain the calculation codes and ensure a better evaluation of the total (n, xn) cross section. The experimental setup and the data analysis method will be presented. The preliminary experimental results for the ^{183}W isotope will be compared to predictions from TALYS nuclear reaction code.

1 Motivation

The development of nuclear reactor project relies essentially on evaluated nuclear reaction databases for numerical simulations, to optimize and predict performance and control parameters. However, these databases still have significant uncertainties, which makes it impossible to reach the required precision in calculations. New measurements and more accurate theoretical descriptions of the involved reactions are needed to improve the evaluated databases. Inelastic neutron scattering reactions, noted (n, xn) , are among the reactions of interest as they modify the neutron spectrum, the neutron population, and produce radioactive species.

The CNRS-IPHC group is running an experimental program with the GRAPHEME [1] setup installed at the neutron beam facility EC/JRC-GELINA [2, 3] (Geel, Belgium) to measure $(n, xn\gamma)$ reaction cross-sections using prompt gamma-ray spectroscopy and neutron energy determination by time-of-flight [4–6]. The obtained exclusive experimental data provide strong constraints on nuclear reaction models. So far, data for isotopes such as ^{232}Th [7], ^{235}U [8], ^{238}U [12], $^{182,184,186}\text{W}$ [10] have been recorded and analyzed.

Tungsten is not an active element in nuclear reactors, but, because of its chemical and mechanical properties, it is used in many alloys. The interaction of neutrons with tungsten is therefore of importance for reactor physics, in particular for fusion reactors, in which tungsten is one of

the most exposed materials to high energy neutrons. From a theoretical point of view, a better description of (n, xn) reactions on tungsten nuclei allows an improvement of models for other key nuclei in reactor fuel. Indeed, tungsten isotopes are deformed like actinides, but also easier to describe as they do not present a neutron-induced fission channel. Still, there are very few measurements available today to test evaluations [11]. Our new experimental data will provide an extensive and constraining test to the predictability of models

2 Experimental setup

The measurement of $^{183}\text{W}(n, xn\gamma)$ cross-section have been performed in 2012 and analysis started recently. As of today, there is no (n, n') cross-section data available – only some $(n, 2n)$ and some (n, n') -level are registered in [11].

The $(n, xn\gamma)$ cross-section measurements are performed with the GRAPHEME setup at the JRC-Geel. It is made up of four High Purity Germanium detectors surrounding the target of interest (here, ^{183}W) and a fission chamber upstream. The neutron flux is determined using the fission chamber. The energy of the reacting neutrons are calculated from their time of flight. The data analysis was performed by methods that were recently detailed in reference [12].

In the following, only the preliminary γ yields (i.e. non-normalized γ to neutron counts ratio) will be presented. The results are compared to default TALYS-1.8 calculations [13].

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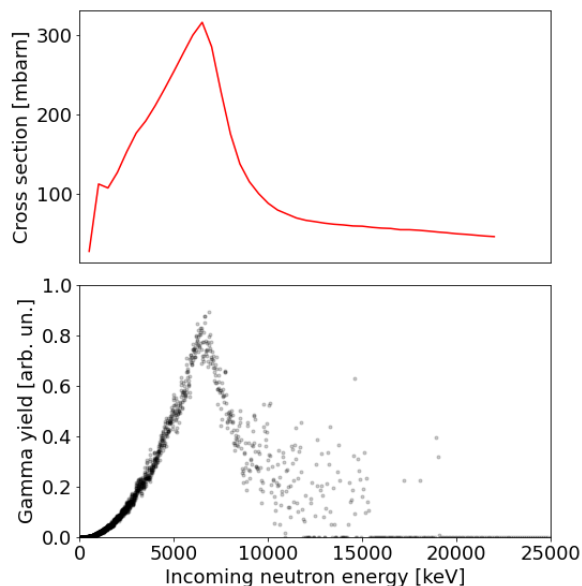


Figure 1. (Top) Talys calculated cross-section for the 209 keV γ -ray in $^{183}\text{W}(n, n' \gamma)$ reaction. (Bottom) Experimental γ ray yield ($\propto N_\gamma/N_{\text{neutrons}}$) for the same transition. (Note: The two graphs share the same neutron energy axis, the y-axis scales are different.)

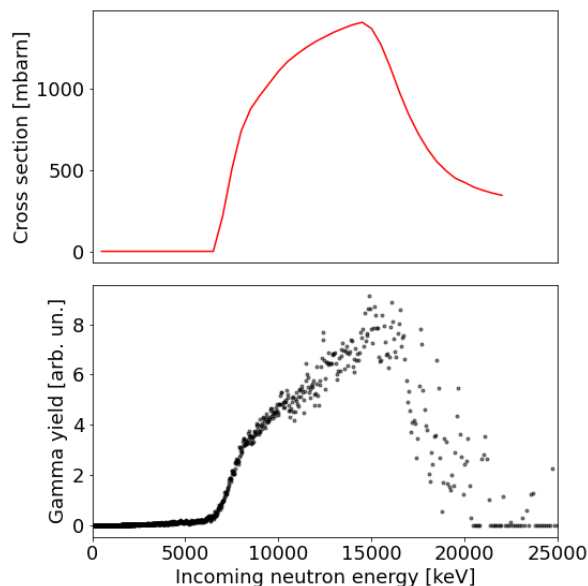


Figure 3. (Top) Talys calculated cross-section for the 229 keV γ -ray in $^{183}\text{W}(n, 2n \gamma)^{182}\text{W}$ reaction. (Bottom) Experimental γ ray yields for the same transition. (Same neutron energy axis, different y-axis scales between the two graphs.)

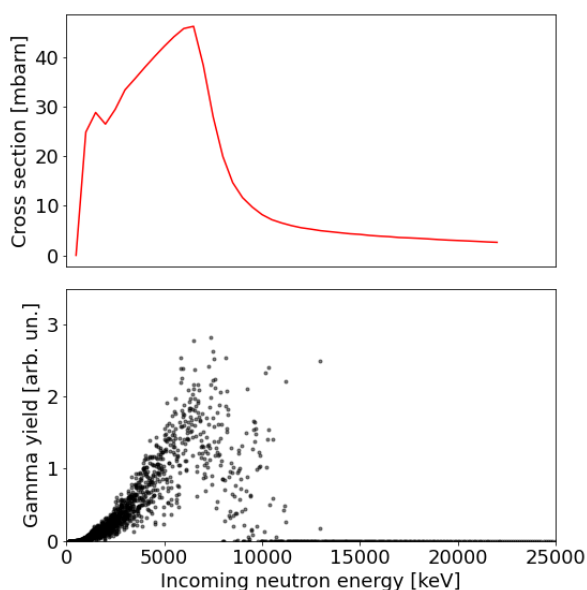


Figure 2. Same as figure 1 for the 259 keV γ ray.

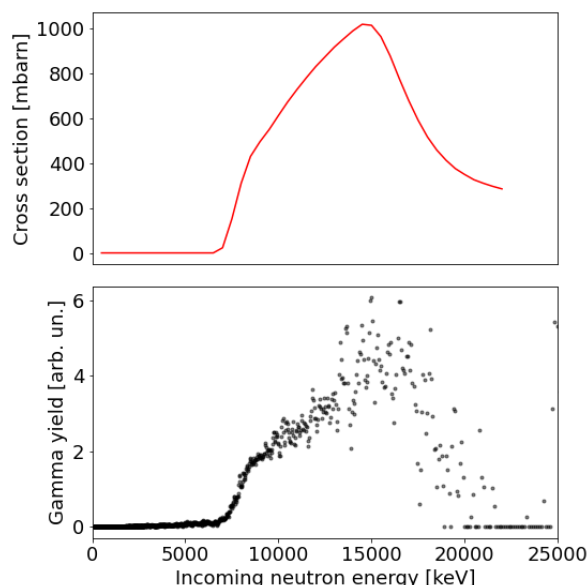


Figure 4. Same as figure 3 for the 351 keV γ ray.

3 Results

Two transitions in the $(n, n' \gamma)$ channel have been extracted. The $5/2_{308.9 \text{ keV}}^-$ to $5/2_{99.1 \text{ keV}}^-$, with an energy of 209.8 keV, and the $5/2_{551.2 \text{ keV}}^-$ to $5/2_{291.7 \text{ keV}}^-$ with an energy of 259 keV. Figures 1 and 2 show the two transitions γ yields.

We also present two transitions in the $^{183}\text{W}(n, 2n \gamma)^{182}\text{W}$ channel. The $4^+_{329.4 \text{ keV}}$ to $2^+_{100.1 \text{ keV}}$,

with an energy of 229.32 keV – figure 3, and the $6^+_{680.4 \text{ keV}}$ to $4^-_{329.4 \text{ keV}}$ with an energy of 351 keV – figure 4.

We see in the figures 1, 2 3 and 4 that the shapes of the yields are compatible with Talys predictions. In particular, the $(n n' \gamma)$ yields fall once the neutron energy gets above the neutron separation energy (6.2 MeV [14]). Likewise, the $(n 2n)$ channel opens up above S_n and grows until slightly (≈ 2 MeV) above S_{2n} (14.25 MeV). The overall shapes (position of the maximums, slopes, ...) are similar.

4 Conclusion

We extracted some preliminary $(n, n' \gamma)$ and $(n, 2n \gamma)$ yields from the data has been recorded with GRAPhEME. They present similar shapes than the one observed in TALYS calculations and in accordance with expected physics (thresholds, ...). Therefore, we are confident that once the full analysis is performed, it will produce high quality cross-section data for several $(n, n' \gamma)$ and $(n, 2n \gamma)$ channels.

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