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Neutron capture cross section of ^{85}Kr

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Abstract. Neutron capture and β^--decay are competing branches of the *s*-process nucleosynthesis path at ^{85}Kr, which makes it an important branching point. The knowledge of its neutron capture cross section is therefore an essential tool to constrain stellar models of nucleosynthesis. The goal is the measurement of the ^{85}Kr(n,γ) cross section via the time-of-flight method. For this, several methods for the production of ^{85}Kr will be investigated. One of these is the irradiation of a ^{82}Se target with an α-beam. Here, the produced ^{85}Kr stays trapped inside the crystalline structure of the selenium. Due to technical difficulties and low yields, an alternative method is the use of reactor produced ^{85}Kr. For future measurements of the neutron capture cross section of ^{85}Kr at FRANZ (Frankfurter Neutronenquelle am Stern-Gerlach-Zentrum), the goal is the use of a target with a high isotopic purity to reduce the background from ^{83}Kr.

1. Motivation

A part of the *s*-process path and a matter of great interest over the years has been the isotope ^{85}Kr [1]. It represents a branching point in the *s* process [2, 3], because the β-decay rate and the neutron capture rate compete. Therefore the mass flow during the *s* process depends on the stellar conditions during the production, like temperature and neutron density.

Besides its importance for the *s* process, ^{85}Kr is of interest in other applications as well. It could for example, help to constrain the broad distribution of ^{86}Kr/^{82}Kr ratios observed in presolar grains, small SiC bonds, that are believed to grow in the outer regions of Red Giants. Trapped inside the SiC crystal matrix are isotopes that can than be examined further. At the moment, the understanding of the ^{86}Kr distribution is only hindered by the poorly known neutron capture cross section of ^{85}Kr.

Furthermore, ^{85}Kr serves as an important part in the Rb/Sr cosmochronometer as it influences the production of ^{87}Rb, which in turn feeds ^{87}Sr. This impact on the ratio of the stable isotopes ^{86}Sr/^{87}Sr could be used to constrain cosmological models of the universe.

2. Target Production via ^{82}Se(α,n)

2.1. Sample preparation

For the measurement of the reaction ^{85}Kr(n,γ) a sufficiently pure sample has to be produced. An anticipated challenge is the presence of other isotopes, which will cause background. For the experiment at Physikalisch-Technische Bundesanstalt (PTB) the α-beam was entirely stopped in the target material, a thick target layer of Se was produced by melting Se onto an aluminum backing. The selenium powder was placed in the gap in the center of the backing and heated in an oven to its melting point of 221°C. To achieve a homogeneous layer of Se, which was essential for an activation experiment, several steps had to be undertaken. First, the droplets were spread mechanically using a spattle after reducing the oven temperature to approximately 100 °C. Afterwards more selenium powder was put in the gap as a part of it remained on the spattle. The heating procedure was repeated until a smooth glassy black layer of Se was formed. The resulting thicknesses of the Se layers were between 240 μm and 400 μm based on the weight of the samples. This was sufficient for the planned experiment as the range of α-particles of 15 MeV in Se is only 0.1 mm [4].

2.2. Experiment at Physikalisch-Technische Bundesanstalt

In February 2014, the activation experiment ^{nat}Se(α,n) was performed at PTB Braunschweig. The goal was to measure unknown thick target yields and α-induced production cross sections for several different reactions for the first time. In particular ^{82}Se(α,n)^{85}Kr. Several optimizations of the setup would have to be made to produce ^{85}Kr in an amount sufficient for a time-of-flight experiment [5]. The most important is a better cooling to counter the small thermal conductivity of Se, which was the reason that the α-current had to be held at a low level. The spectroscopic analysis of the reaction product ^{85m}Kr was conducted using a High-Purity Germanium (HPGe) detector at PTB. Because of the long half life of the ^{85}Kr ground state and the small intensity of its strongest γ-emission line at 514 keV, it was not possible to use the HPGe detector at PTB for its spectroscopic analysis. Therefore it was undertaken at Goethe University Frankfurt using a Low Energy Photon Spectrometer (LEPS) detector, which has the advantage of a very good energy resolution. This allows the separation of the 514 keV γ-line following the decay of ^{85}Kr^{GS} from the 511 keV background. From the measured thick target yields the preliminary cross sections of ^{85m}Kr and ^{85}Kr have been calculated to $\sigma_{85mKr} = 37.46$ mb and $\sigma_{85Kr} = 124.61$ mb respectively (Figure 1).

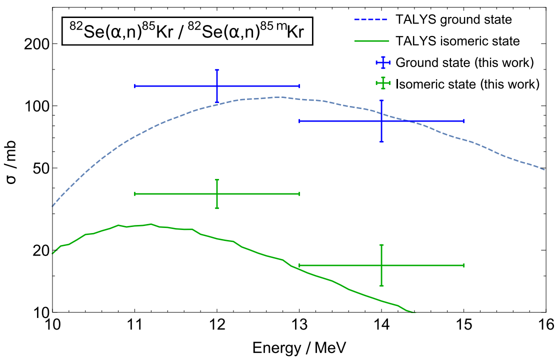

Figure 1. Comparison of determined α-induced production cross section of ^{85}Kr to the theoretically determined from TALYS. The TALYS values are in good agreement with the measured values. The energy error of ± 1 MeV originates from the subtraction of two thick target yields.

3. Target production using reactor produced ^{85}Kr

^{85}Kr is also a product of the fission reaction ^{235}U(n,f) in a nuclear reactor and is with an isotopic abundance of about 12%. Though easier to obtain, reactor produced ^{85}Kr is contaminated with other Kr isotopes, which will cause background during (n,γ) measurements. The biggest problem is ^{83}Kr, which has a higher Q-value than ^{85}Kr. Such a mixed sample, with an isotope ratio of approximately 1.8:3.7:10.6:1:6.2 (^{82}Kr:^{83}Kr:^{84}Kr:^{85}Kr:^{86}Kr), is already available. An additional measurement of pure ^{83}Kr will be necessary as it will produce a significant background during measurement. Except for ^{83}Kr, which has a higher Q-value (10.52 MeV) than ^{85}Kr (9.86 MeV), all other Q-values are smaller than for ^{85}Kr. Therefore capture events on other isotopes can be discriminated applying a Q-value cut [7, 8], provided the measurement is performed using a 4π-γ-detector. To verify that this sample is viable for an ^{85}Kr(n,γ) experiment, simulations with DICEBOX [9] were performed to obtain γ-cascades of the (n,γ) reactions of ^{83}Kr and ^{85}Kr (Figure 2). With these, further simulations with GEANT3 [10] are possible to find a way of distinguishing captures on the two isotopes in a calorimetric measurement.

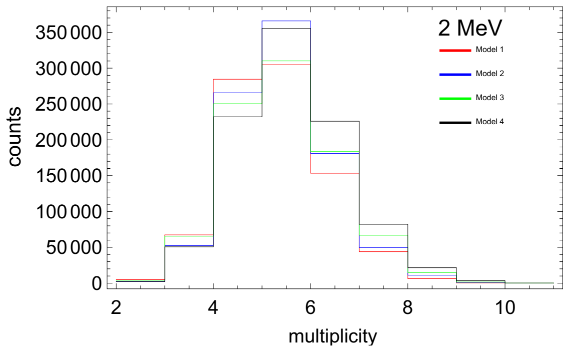

Figure 2. An example result of the DICEBOX simulations of ^{83}Kr. Shown are the multiplicities of all 2 MeV γ's of a cascade.

4. Time of flight experiment

With a suitable sample [5], it will be possible to perform an experiment to investigate the reaction ^{85}Kr(n,γ) at FRANZ (Frankfurter Neutronenquelle am Stern-Gerlach Zentrum) in Frankfurt. Neutrons at FRANZ will be produced via the reaction ^{7}Li(p,n) [3]. The high neutron flux at the sample position will be increased by reducing the neutron flightpath to about 8 cm [11].

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