Measurement of (n, γ) Cross Sections at Stellar Energies for ^{58}Ni and ^{78}Se with GAMS

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We report measurements of stellar neutron capture cross sections which refer to the mass region, which is dominated by the so called "weak" component of the s-process. The reaction flow to the higher mass region depends not only on the abundance of the seed but on its stellar neutron capture cross section as well. Generally these cross sections can be determined directly by measuring the prompt γ-rays associated with the neutron capture via the time-of-flight method (TOF), like e.g. with the Karlsruhe 4π BaF_2 detector. An independent approach is to measure the activation product, where one has also access to partial cross sections leading to isomeric states. For the cross sections of ^{58}Ni and ^{78}Se direct off-line counting of the produced activity is compromised by the long half-lives of the reaction products ($T_{1/2}$(^{59}Ni)=(7.6±0.5)×10^4 a [1] and $T_{1/2}$(^{79}Se)=(2.80±0.36)×10^6 a [2]) and by the absence of suited γ-ray transitions. The measurements reported here are, therefore, based on the detection of the ^{59}Ni and ^{79}Se atoms produced by irradiation of natural Ni and Se samples in a quasi-stellar neutron spectrum of $kT = 25$ keV by accelerator mass spectromerty (AMS). The application of AMS counting in stellar neutron reactions, which has been demonstrated recently [3], has the further advantage of being independent of uncertain γ-ray intensities.

- ^{58}Ni(n,γ)^{59}Ni

  Next to ^{56}Fe, which represents the most important seed for the s-process path, ^{58}Ni constitutes also a significant fraction of the seed. Existing data of the neutron stellar cross sections at $kT = 25$ keV are based on time-of-flight (TOF) measurements [4,5,6] with quoted systematic uncertainties of about 5%. Though all three data sets are in fair agreement, a comparision with the result of an alternative method could add confidence in the value.

- ^{78}Se(n,γ)^{79}Se

  So far, there is no experimental information on the stellar (n, γ) cross section of ^{78}Se. The activation data are essential for evaluating the important branching in the s-process reaction path at ^{79}Se. The terrestrial half-life of ^{79}Se is drastically reduced under stellar conditions via thermal population of the low-lying isomeric state ($I^{\pi} = 1/2^-$ at $E_\gamma = 96$ keV, $T_{1/2}$= 3.9 min with a small beta-decay branch and a partial half-life of 4×10^5 s [7]). Therefore β-decay can compete with neutron capture at temperatures above 1.5×10^8 K. The strength of the resulting branching is reflected in the s-only isotopes ^{80,82}Kr. Analysis of the local abundance pattern in the mass region $80 \geq A \geq 82$ allows to deduce the effective half-life of ^{79}Se at the s-process site. Since the temperature dependence of the half-life is well known [7], the branching at ^{79}Se can be interpreted as an s-process thermometer [8].

Both samples were activated at the Karlsruhe 3.7 MV Van de Graaff accelerator. Neutrons were produced with the ^{7}Li$(p,n)^7$Be source by bombarding 30 μm thick layers of metallic Li on a water-cooled Cu backing with protons of 1912 keV, 30 keV above the reaction threshold. The resulting quasi-stellar neutron spectrum approximates a Maxwellian distribution for kT=(25.0±0.5) keV [9] with a maximum neutron energy of 108 keV.

Both samples were prepared from natural compounds (23.77% ^{78}Se and 68.077% ^{58}Ni). For the Se measurement, two pellets from CdSe and pure Se metal were prepared and activated in parallel in a double sandwich with three gold foils. The measurement of ^{79}Se is demanding, see e.g. [10]. For the determination of the cross section with the GAMS, only the CdSe sample could be used due to a rather high ^{79}Br background in the Se sample. For the Ni samples, two thin samples were cut from Ni foils and activated in a sandwich with two gold foils.

For the AMS-measurement of ^{59}Ni the nickel foil gives a high rate of the isobar ^{59}Co. After a chemical treatment the cobalt rate was reduced by two orders of magnitude. With the GAMS setup we measured a ratio of (2.53±0.15) ×10^{-11} ^{59}Ni/Ni. A blank sample with similar cobalt content yielded a ratio two orders of magnitude lower.

The preliminary results deduced with our experimental neutron distribution, resulting in $\sigma_{exp}(kT = 25\,\text{keV})$ of 27.2±2.1 mb and 61±10 mb, respectively, for the neutron captures of ^{58}Ni and ^{78}Se.

Sample	N_{act}/N	σ(exp)[mb]
Ni	(2.53±0.15)×10^{-11}	27.2±2.1
CdSe	(1.19±0.19)×10^{-10}	61±10

Table 1: Preliminary results from our measurements

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