Production of a New ^{79}Se Standard for AMS

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The nucleosynthesis of elements heavier than iron can be almost completely ascribed to the *s* process ("slow neutron capture process") and the *r* process ("rapid neutron capture process"). The *s* process can be further divided into a "weak" component (responsible for nuclei up to $A\approx 90$) and a "main" component (for $90<A<209$), which occur in different astrophysical scenarios at different temperatures and with different neutron exposures. Among the nuclei involved, the long-lived radioactive isotopes ^{63}Ni ($t_{1/2}$= 100.1 yr), ^{79}Se ($t_{1/2}$ ≈295000 yr), and ^{83}Kr ($t_{1/2}$= 10.76 yr) assume key positions, because their β^--decay rate becomes comparable to the neutron capture rate ($\lambda_\beta\approx\lambda_n$). The resulting competition leads to branchings in the *s*-process nucleosynthesis path.

These branching isotopes can be used either to determine the neutron density or the temperature in the star during the *s* process. The strong temperature dependence of the β-decay rate of ^{79}Se [1] is due to thermal population of low-lying excited states and reduces the half-life from the terrestrial value of 295000 yr to only a few years at *s*-process temperatures of 5 MK. Due to this behavior ^{79}Se can be used as *s*-process thermometer and the increase in the abundance of the *s*-only isotope ^{80}Kr can be used to deduce the effective temperature. ^{63}Ni and ^{85}Kr do not show such a strong temperature dependence and are thus ideal neutron density monitors.

With the GAMS setup at the MLL, we have determined in the last years the stellar (n,γ) cross sections of ^{62}Ni and ^{78}Se at kT=25 keV (see Annual Report 2005, p. 27 and Annual Report 2007, p. 27). The detection of ^{79}Se is also of interest for nuclear technology because due to its long half-life it has been build up in burnt reactor fuel elements. Its still uncertain half-life (presently favored value: 295000 yr) makes a determination of the ^{79}Se amount via the activity very uncertain. AMS is one of the few possibilities for direct atom counting. But since the measurements are always carried out relative to a standard the production of these standards is a critical point.

The previously used ^{79}Se standard was produced with thermal neutrons and had an uncertainty of 6%, mainly due to the uncertainty in the thermal neutron capture cross section of 0.43±0.02 b [2]. An alternative way to produce a ^{79}Se standard independent of the thermal cross section is the reaction chain $^{82}\mathrm{Se}(p,\alpha)^{79}\mathrm{As}(\beta^-)^{79}\mathrm{Se}$. This activation was carried out at the cyclotron of the Physikalisch-Technische Bundesanstalt in Braunschweig/Germany. The sample consisted of Al powder mixed with ^{82}Se (enrichment 99.93%) in the stoichiometry of 8.5:1. Because no experimental information existed so far, the sample was irradiated with protons of $E_{c.m.}$=18.625 MeV (see Fig. 1), close to the (theoretical) cross section maximum for the $^{82}\mathrm{Se}(p,\alpha)^{79}\mathrm{As}$ reaction in the Hauser-Feshbach code NON-SMOKER [3].

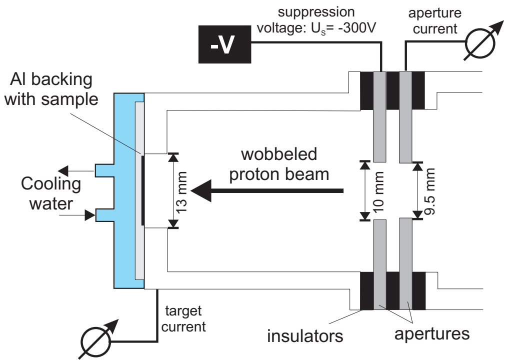

Fig. 1: Target cup setup at the PTB.

For determining the cross section, six short-time activations between 60 and 150 s have been carried out. The decay of the ^{79}As can then be followed with γ spectroscopy (see Fig. 2). The transitions at 365 keV, 432 keV, and 879 keV were used for analysis. However, there seem to be systematic deviations between the single transitions.

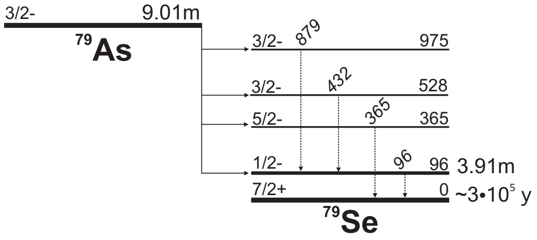

Fig. 2: Decay scheme of ^{79}As.

The preliminary results (including only the statistical errors) are 9.7±0.4 mb, 11.4±0.2 mb, and 10.8±0.3 mb for the 365 keV, 432 keV, and 879 keV transitions, respectively. The origin of these deviations might be due to the uncertainties in the γ intensities, which were deduced with 5% uncertainty more than 40 years ago. Taking the weighted average, we get a preliminary production cross section of 10.6±0.7 mb, which translates with the total proton fluence of 1.2×10^{18} p into a production of 2.3×10^{12} atoms of ^{79}Se, and a $\frac{^{79}Se}{^{82}Se}$ ratio of 1.3×10^{-8}.

References

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[2] S.F. Mughabghab, Atlas of Neutron Resonances- Resonance Parameters and Thermal Cross Sections Z= 1-100, 5th Edition, Elsevier (2006), ISBN 0444 52035X.
[3] T. Rauscher and F.-K. Thielemann, At. Data Nucl. Data Tables **75** (2000) 1