First application of calorimetric low temperature detectors in accelerator mass spectrometry

S. Kraft,[a,b] V. Andrianov,[a,b] A. Bleile,[a,b] P. Egelhof,[a,b] R. Golser,[c] A. Kiseleva,[a] O. Kiselev,[a] W. Kutschera,[c] J. P. Meier,[a,b] A. Priller,[c] A. Shrivastava,[a,b] P. Steier,[c] C. Vockenhuber[c]

[a]Gesellschaft für Schwerionenforschung, Darmstadt, Germany; [b]Institut für Physik, Johannes Gutenberg Universität, Mainz, Germany; [c]VERA Laboratory, Institut für Isotopenforschung und Kernphysik, Universität Wien, Wien, Austria

Accelerator mass spectrometry (AMS) is a well known method for determination of very small isotope ratios with high sensitivity. ^{236}U represents one of the heaviest nuclides of interest for AMS. Being produced in nature by capture of thermal neutrons in the reaction ^{235}U(n,γ)^{236}U and having a half-life of 23.4 million years, the relative abundance of ^{236}U provides an excellent neutron flux monitor integrated over geological time scales [1]. Thus, besides other applications, ^{236}U can be used to prove the existence of an enhanced neutron flux due to natural "reactor-like" conditions. In natural uranium, the isotope ratio is expected to be of the order of ^{236}U/^{238}U = 10^{-10}-10^{-14}, dependent on its history.

The investigations presented in the following have been performed at the Vienna AMS facility VERA. Under the present conditions at this facility, background in AMS measurements for very heavy ions is mainly due to neighbouring isotopes which have, due to various charge exchange processes, the same magnetic rigidity $M \cdot E/q^2$ (see ref. [1] for detailed discussion). The level of ^{236}U/^{238}U ratio reached was limited to 6 x 10^{-11}, mainly due to the limited detection efficiency and/or energy resolution of the conventionally used TOF/energy detector. Calorimetric low temperature detectors (CLTDs) have already been demonstrated [2] to provide an excellent energy resolution, a linear energy response and high detection efficiency for relatively low ion energies E = 0.1-1 MeV/amu, typical for AMS. Such detectors are therefore well suited to replace the standard TOF/energy detection scheme and to resolve the isotope of interest from neighbouring isotopes leaking through the magnetic and electrostatic filters of VERA by their high energy resolution power alone. The aim of the present investigations was to apply CLTDs in an AMS experiment for determination of the isotope ratio of ^{236}U/^{238}U for various samples of natural uranium in order to establish a precise material standard and to improve the level of sensitivity.

For the determination of the isotope ratio, the radioisotope ^{236}U was detected in the CLTD, while for the "stable" ^{238}U the beam current was measured in a Faraday cup. For detailed description of AMS measurement procedure see [1]. The detectors used consist of a thin film superconducting aluminium strip thermometer operated at T ~ 1.5 K, which is evaporated onto a 0.33 x 7.5 mm^3 sapphire substrate serving as absorber (for details see [2] and refs. therein). The detector performance was tested using a beam of ^{238}U, reduced in intensity, with an energy of E = 17.39 MeV. The energy spectrum obtained is displayed in fig. 1. Compared to previous measurements [2], energy resolution was improved to ΔE = 80 keV, corresponding to a relative resolution of ΔE/E = 4.6 x 10^{-3}. For the first AMS measurements presented below, the detector performance under running conditions was unfortunately worse, but already with a resolution of ΔE/E = 9.1 x 10^{-3}, essential parts of background could be separated.

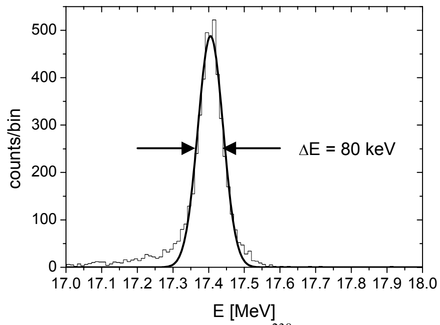

Fig. 1: Energy spectrum for ^{238}U at E = 17.39 MeV.

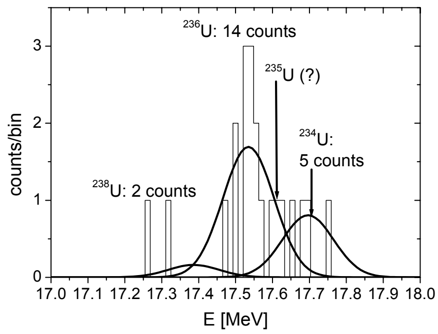

Fig. 2: AMS measurement for sample from Bad Gastein spring water.

Several samples of natural uranium were investigated: Uranium ore from the mine "Joachimsthal", stored before 1918 and therefore not contaminated by nuclear bomb fallout, is very suitable as a material standard in AMS if its ^{236}U/^{238}U isotope ratio is known precisely. Within errors, the result of ^{236}U/^{238}U = (4.14 ± 0.76) x 10^{-11} is in agreement with previous measurements [1]. Statistical as well as systematical errors were considerably reduced, due to an improvement in detection efficiency from 20% to 65%. With the increase in sensitivity obtained, it was possible for the first time to investigate one sample of uranium extracted from spring water from Bad Gastein, Austria, for which an isotope ratio of ^{236}U/^{238}U < 10^{-12} was expected. Fig. 2 shows the energy spectrum obtained. The result for the isotope ratio is (6.5 ± 2.2) x 10^{-12}, representing the smallest isotope ratio ever measured for ^{236}U/^{238}U. Future experiments with optimized energy resolution and increased detection efficiency will allow to measure even smaller ^{236}U/^{238}U ratios.

References:

[1] C. Vockenhuber et al., Int. J. Mass. Spec. **223-224** (2003) 713

[2] S. Kraft et al., AIP Conf. Proc. **605** (2002) 405