Transport of fission products using a gas-jet with dry ice aerosol particles

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Introduction: The TRIGA-SPEC experiment [1], which is installed at the TRIGA Mainz reactor aims to determine nuclear ground-state properties of neutron-rich fission products like masses, magnetic moments, spin and charge radii in a model independent way by means of Penning trap mass spectrometry and laser spectroscopy. Neutron-rich fission products are produced at the TRIGA Mainz reactor in a target chamber containing a fissionable target, e.g. ^{235}U or ^{249}Cf close to the reactor core. To transfer these products to the TRIGA-SPEC setup, a gas-jet system using N_2/CO_2 or CO_2 gas and dry ice aerosol particles has been tested.

Experiment: Dry ice aerosol particles were produced by allowing liquid CO_2 (kept at a pressure of about 60 bars) to expand to atmospheric pressure through a nozzle. In the expansion zone behind the nozzle solid dry ice particles (clusters) form and flow together with the carrier gas through a polyethylene capillary to the target chamber.
Using an electrostatic classifier we measured the particle size distribution [2]. At a gas flow rate of 1.0 l/min particle diameters were from 10 nm to 500 nm lognormally distributed around a maximum at about 80 nm, however, the mean size decreased to 30 nm within 30 min. The gas-jet containing these particles was fed into the target chamber, which was equipped with a ^{249}Cf target. The reactor was operated at a thermal power of 100 kW. The fission products were thermalized in the gas at a pressure of about 2.5 bars, attached to dry ice aerosol particles, and were flushed out of the target chamber in a laminar flow through a 8-m long capillary of 0.5 mm inner diameter to a glass-fiber filter, where they were collected. The transport efficiency from the target chamber to the filter was measured. Sample collection lasted for 4 min. Measurement of the filter with a Ge(Li) γ-detector was started 1 min after the end of collection. A typical spectrum is shown in Fig.1.

Results: The extraction of fission products using dry ice aerosol particles was demonstrated for different gas flows of CO_2 and N_2 (see Fig.2). The transport efficiency will be investigated in detail. Values up to 60% (relative to a N_2/KCl gas-jet) have been reached in first tests.

Outlook: The gas-jet will be connected to a skimmer system where the gas will be separated from the aerosol particles. To release the fission products from the aerosol particles and to ionize them, an ECR ion source is being installed on a high-voltage platform [3]. After ionization the fission products will be mass separated in a 90° dipole magnet and finally transferred either towards the laser spectroscopy experiment TRIGA-LASER or the Penning trap mass spectrometer TRIGA-TRAP.

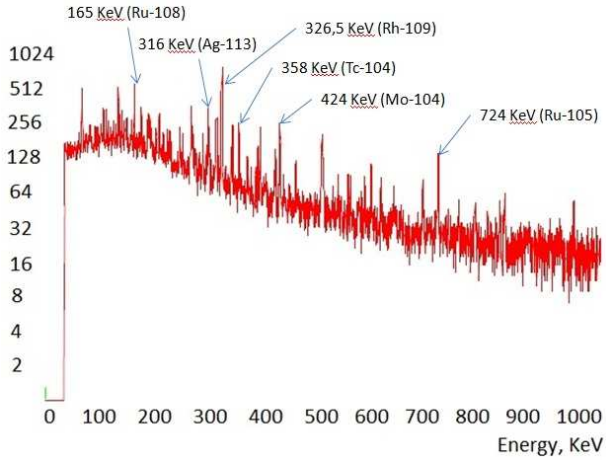

Figure 1. γ-spectrum of fission products obtained at a gas flow of 250 ml/min of CO_2 and 250 ml/min of N_2. Some prominent γ-rays are labeled in the spectrum.

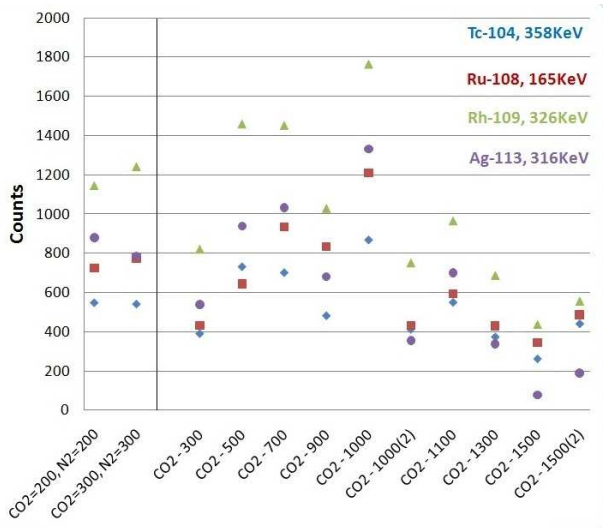

Figure 2. Relative yield of different fission products (Tc-104, Ru-108, Rh-109 and Ag-113) as a function of the gas flow rate.

References

[1] J. Ketelaer et al., Nucl. Instr. Meth. A 594 (2008) 162-177.
[2] M. Eibach et al., Nucl. Instr. Meth. A 613, (2010) 226-231.
[3] M. Eibach et al., this report.

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