Determination of the ^{233}Pa(n,f) reaction cross section for thorium fueled reactors

F. Tovesson[1,2], F.-J. Hambsch[1], A. Oberstedt[2], B. Fogelberg[3], E. Ramström[2,3] , S. Oberstedt[1], H. Bax[1]

(1) EC-JRC-Institute of Reference Materials and Measurements (IRMM), Retieseweg, B-2440 Geel, Belgium
{2} Örebro University, Inst. för Naturvetenskap, S-70182 Örebro
{3} Studsvik Neutron Research Laboratory, Uppsala University, S-61182 Nyköping, Sweden

In recent years there has been a renewed interest in the thorium cycle in connection with transmutation of waste and accelerator driven systems (ADS). The concept of the energy amplifier (EA) (1), for example, combines the two in a hybrid system based on the thorium fuel cycle and a spallation neutron source. Successful development and implementation of these concepts are, of course, strongly relying on accurate neutron-induced reaction data. By comparing the different neutron data bases available it becomes evident that for some cross-sections large discrepancies exist, even in the well studied region of neutron energies up to 20 MeV which normally sets the limit to what is of interest for conventional nuclear technologies.

One example where existing evaluations are deviating from each other is the neutron induced fission cross section of ^{233}Pa. This protactinium isotope plays an important role in the thorium cycle as an intermediate step between the ^{232}Th source material and the ^{233}U fuel material. Hence, knowledge of the ^{233}Pa (n,f) cross-section is necessary in a reactor scenario in order to estimate the balance of nuclei. To the knowledge of the authors there exist only one experimental investigation of the fast neutron induced fission cross section of ^{233}Pa (2), dating back to 1967. The measured value was 775 ± 190 mb for fast neutrons, but the neutron spectrum was not very well known. The available evaluations of the reaction in databases such as ENDF and JENDL-3 show that the above threshold cross-section differs of about a factor two and also that the threshold energy varies between about 0.8 and 1.5 MeV. The main reasons why so little experimental data existed up to now is the high activity (7.7 10^{14} Bq g^{-1}) and short half-life (27.0 days) of the isotope. Another difficulty is introduced by the in-growth of ^{233}U which has an epi-thermal cross-section much higher than for fast neutrons. Thus, any degree of thermal or epi-thermal background would immediately affect the measurement.

In order to resolve the existing discrepancies between the different evaluations an experiment was set up to measure the ^{233}Pa(n,f) reaction cross section for neutron energies up to 10 MeV. A sample of 0.5 μg ^{233}Pa was breeded and separated out of the ^{233}Th mother solution at the Studsvik Neutron Research Laboratory in Nyköping, Sweden. The measurements were then performed at the Van de Graaff accelerator facility at the Institute of Reference Materials and Measurements (IRMM) in Geel, Belgium. An ionization chamber was used as fission fragment detector and the cross-section of ^{233}Pa was measured in a back-to-back geometry relative to ^{237}Np. In the present measuring campaign five neutron energy points between 1.0 and 7.5 MeV were investigated. The cross-sections determined so far are lower than predicted by any evaluations and also show a lower threshold energy.

The average above threshold preliminary fission cross-section has a value of about 350 ± 30 mb. At 7.5 MeV, above the second chance fission threshold, a preliminary value of 660 ± 110 mb was measured.

(1) F. Carminati et. al., "An energy amplifier for cleaner and inexhaustible nuclear energy production driven by a particle beam accelerator", CERN/AT/93-47(ET), 1st November, 1993.
(2) H. R. von Gunten, R. F. Buchanan, A Wyttenbach and K Behringer, Nucl. Sci. and Eng. {**27**} (1967).