Beta decay studies of fission products by total absorption spectroscopy

Abstract

The dissertation presents the results of the β decay measurement of eight fission products, ie. ^{86}Br, ^{89,90}Kr, ^{89,90gs,90m,92}Rb and ^{139}Xe using the Modular Total Absorption Spectrometer (MTAS).

Thanks to its high efficiency for the detection of γ-radiation, total absorption spectroscopy is an ideal technique to establish the true β-decay feeding. The knowledge of the decay scheme is then used to determine the average γ and β energy as well as the distribution of antineutrino energy released in the decay. The average γ and β energies are an important observable for the calculation of the decay heat released from fission products. The antineutrino energy spectrum is used to calculate the total antineutrino flux emitted by reactor cores and the number of reactor antineutrino interactions with the detector matter.

The experiment was performed at the Holifeld Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL). The 40 MeV proton beam impinged on a ^{238}UC$_x$ target placed inside the plasma ion source. Fission products were mass selected by means of magnetic separation and implanted into a moving tape that transported the radioactive samples into the center of MTAS where they were measured, and then moved them away. An important part of this work was the development of the metodology for the analysis of data from the MTAS spectrometer. A Monte Carlo simulation code was developed by means of the Geant4 toolkit to reproduce the response function of the MTAS detector and the experimental spectrum reconstruction agorithm was implemented.

For most of the measured nuclides, the average electromagnetic energy from experimental MTAS data was obtained and found to be larger than the value deduced from the ENSDF database, while the average β and antineutrino energies were decreased. This led to a reduction of the number of antineutrino interactions with the matter.

The results were used to determine of the decay heat release from fission products of ^{235}U and ^{239}Pu. The improvement between the experimental points and the calculated curve for the electromagnetic component of the decay heat was achieved. The least-squares estimator χ^2 changed from 211 to 167 for ^{235}U and from 152 to 146 for ^{239}Pu. In addition, the expected growth of the electromagnetic component of the decay heat after taking into

account the results of the total absorption spectroscopy measurement was proved.

When compared with the current ENSDF data, the calculated total number of reactor antineutrino interactions with the matter was reduced by 1.5%, 0.7%, 0.9%, 0.6% for the fission of ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu respectively.