Beta decay of neutron rich bromine isotopes studied by means of Modular Total Absorption Spectrometer*

M. Stepaniuk[1], M. Karny[1], A. Fijalkowska[1,2], K. P. Rykaczewski[3], B. C. Rasco[3], R. Grzywacz[2,3,4], C. J. Gross[3], M. Wolinska-Cichocka[5], K. C. Goetz[2,6], D. W. Stracener[3], R. Goans[7], J. H. Hamilton[8], J. W. Johnson[3], C. Jost[2], M. Madurga[2], K. Miernik[1,3], P. Shuai[2,3,4,9], D. Miller[2], S. W. Padgett[2], S. V. Paulauskas[2], A. V. Ramayya[8], and E. F. Zganjar[10]

[1]*Faculty of Physics, University of Warsaw, PL-02-093 Warsaw, Poland*
[2]*Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37966, USA*
[3]*Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*
[4]*JINPA, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*
[5]*Heavy Ion Laboratory, University of Warsaw, PL-02-093 Warsaw, Poland*
[6]*CIRE Bredesen Center, University of Tennessee, Knoxville, Tennessee 37966, USA*
[7]*Oak Ridge Associated Universities, Oak Ridge, Tennessee 37831, USA*
[8]*Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235, USA*
[9]*Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, Gansu 730000, China and*
[10]*Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA*

Results of the β decay of neutron rich bromine isotopes from mass A=87 to A=91 measured with Modular Total Absorption Spectrometer (MTAS) will be presented. Neutron rich bromine isotopes have high ^{235}U cumulative fission yields and large Q_β energies, therefore they make substantial contributions to the reactor decay heat and may create many detectable reactor anti-neutrinos. These large contributions means a complete knowledge of the decay schemes, including β-n branches, is of the utmost importance.

Decay schemes from ENSDF database of all discussed bromine isotopes have been found to be insufficient and incomplete, compared to the results of MTAS measurements. For example, even though the decay of ^{87}Br is a relatively well studied case (161 known levels, 226 known γ-transitions), our analysis shows a missing β-feedings to highly excited levels as well as incomplete γ-decay patterns for the known levels. Published ^{91}Br decay scheme lacks information on all β-feedings and γ-transitions intensities. Starting from the existing decay schemes of bromine isotopes, we present more complete pattern of β decays deduced from MTAS data, using known levels and introducing so-called pseudo-levels where needed. Average β and γ-transitions energies are calculated as a result. Our analysis uses a multi spectra simultaneous fitting technique, which fits β-decay branches to the experimental spectra from individual modules and to the sums of experimental spectra, in parallel with the total MTAS energy spectrum.

Large Q_β energies lead to wide $Q_{\beta n}$ energy windows, what makes all isotopes in question a delayed neutron emitters. Modular Total Absorption Spectrometer, because of its volume, allows for a direct neutron measurements, thanks to neutron scatterings and captures inside NaI(Tl) crystals. Analysis results consist of estimation of P_n values, neutron energy spectra and neutron transitions to excited energy states in corresponding daughter nuclei. In the decay of ^{91}Br four β delayed neutron transitions to the excited states in ^{90}Kr have been observed for the first time.

In summary, analysis results of the MTAS data for neutron-rich, β-delayed neutron emitting bromine isotopes from mass A=87 to A=91 will be shown. Beta-neutron transitions to excited states in daughter nuclei will be discussed, as they are clearly visible in MTAS spectra. The impact of the evaluated isotopes on reactor decay heat calculations as well as on the reactor anti-neutrino anomaly will also be presented.

---

*This work was partially supported by the National Science Centre, Poland (NCN), under grant 2016/23/B/ST2/03559, and by the Office of Nuclear Physics, U.S. Department of Energy under Contracts No. DE-AC05-00OR22725 and FOA 18-1903 (ORNL), No. DEFG02- 96ER40983 (UTK) and by the Office of Science.