Beta decay studies of bromine isotopes with mass numbers from A=87 to A=91 by means of the Modular Total Absorption Spectrometer

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Abstract

The dissertation analyzed the β decays of isotopes $^{87-91}$Br and ^{91}Kr, using data obtained in 2012 and 2015 at HRIBF in Oak Ridge National Laboratory with the Modular Total Absorption Spectrometer (MTAS). New MTAS decay schemes were developed, including previously unknown levels, γ transitions, and neutron energies in β-n transitions. For ^{91}Br, the first complete decay scheme was presented. The results were incorporated into the calculations of reactor decay heat and antineutrino flux.

The probabilities of β-delayed neutron emissions (P_n) for $^{87-91}$Br were determined to be 2.36(24)%, 6.4(6)%, 15.1(19)%, 24.2(30)%, and 30.6(40)%, respectively. β-n-γ transitions to excited states of daughter nuclei were investigated, and their intensities were determined. New β-n-γ transitions were identified for the decays of ^{90}Br and ^{91}Br. Half-lives for $^{87-90}$Br were determined and found to agree with literature values.

The competition between neutron and γ emission from levels above the neutron separation energy was discussed. In the β decays of ^{87,88,89,91}Br, de-excitation via γ emission occurs with a probability of 20–50%, while for ^{90}Br, neutron emission is always favored (no competition) due to the high availability of states in the daughter nucleus.

The modified decay schemes enabled more accurate calculations of reactor decay heat. The difference in fit to experimental data for the γ component of ^{235}U decay heat was reduced by 58%, and for the β component of ^{235}U and the γ component of ^{239}Pu, by 12% and 13%, respectively. The detectable reactor antineutrino flux decreased by 2.91%, 2.64%, 1.1%, and 1.07% for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu, respectively, reducing the deficit, known as the reactor antineutrino anomaly, by nearly half.

Studies of high-energy reactor antineutrinos produced in the β decays of ^{88,90,91}Br demonstrated their significant impact on the antineutrino spectrum. In particular, changes in the ^{90}Br decay scheme reduce the high-energy antineutrino spectrum by approximately 40% for ^{235}U.