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Recovery and isolation of hafnium isomers from ¹⁷⁶Yb target irradiated by ⁴He ions in optimized conditions

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Interest to high-spin (16+) long-lived (31 y) 178m2Hf isomer was established since 20 years ago because of a possibility to produce it in a micro-weight amount for consecutive studies of nuclear reactions with high-spin target and for potential application as an energy accumulator. Production of 178m2Hf was described in [1] via spallation of Ta by protons at LAMP facility and via 176Yb(4He,2n) reaction at Dubna cyclotron [2]. Series of experiments with the 178m2Hf target had been carried out due to cooperation of FLNR with European research centers and the results were summarized in [3] and refs. therein. On today, the innovative perspectives for creation of tiny energy sources support the continuing interest to 178m2Hf.
In the present report, we describe an optimized production of 178m2Hf using the 176Yb target of special construction irradiated at internal beam of the U-200 cyclotron in Dubna. The 96% enriched 176Yb oxide was deposited onto water-cooled Al backing, and the target surface was inclined to the beam at angle near 10 degrees. The target thickness of 7 mg/cm2 has provided effective thickness in a beam direction of about 80 mg/cm2 in ligature weight. The 4He+1 ions reach an energy of 35 MeV. With beam intensity limited to be lower 15 microA, the corresponding beam power does not exceed 500 W. Such conditions were safe, but the target could stand even at 3 times higher beam intensity. After irradiation the target material Yb2O3 was washed off from the backing with 16 M HNO3 and anion exchange in conc. HCl solution was applied to separate Hf-fraction. With the same purpose precipitation of YbF3 was also tested [4]. Deep purification was carried out using the anion exchange chromatography in HF solutions with an overall chemical yield upon the average 85%. Activity of the irradiation products was controlled by the gamma-spectroscopy method using HPGe spectrometer. All gamma-lines belonged to 178m2Hf and 179m2Hf were quantitatively measured and absolute yields of both high-spin isomers were determined with appropriate accuracy.
Under described conditions several 176Yb targets were irradiated, and, in total, 6e+14 atoms of 178m2Hf were produced over beam time of 900 hours. The isomer cross-section and impurities content obtained in the present experiments are in a good agreement with the data published earlier [2]. Change to the internal beam at the cyclotron and more tangential beam-to-target geometry supply higher yield of the products and make the production method more economic. The position of a target inside the cyclotron camera leads to the decreased neutron flux outside and meets the requirements of modern radiation safety rules. Improving the biological shielding at the accelerator and increasing the beam current, one can expect a productivity of about 3e+15 of the 178m2Hf isomeric material per 1000 hours of effective irradiations.

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