Search for X-ray-induced Decay of the 31-year Isomer of ^{178}Hf at Low X-ray Energies

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Introduction

The 31-yr isomer of ^{178}Hf, at an excitation energy of 2.446 MeV and with J^p, K = 16+, 16, has been the object of several studies for possible mechanisms that might trigger isomer decay to the ground state. The potential for control of nuclear energies (MeV) with atomic energies (keV) is the driving interest. The ^{178}Hf isomer is a favorite nucleus in the search for triggered decay because this isomer is long lived and available in microgram quantities, its decay scheme is well known, its excitation energy is high, and a sample enriched in this isomer can be fabricated for irradiation. In fact, accelerated decay of the ^{178}Hf isomer when irradiated with photons from a dental x-ray machine has been reported by Collins et al. [1]. The triggering x-ray energies were reported to be in the 20- to 60-keV range. By using the synchrotron radiation at the APS, we found [2] limits on such accelerated emission that were approximately 5 orders of magnitude lower than those in Ref. 1. Very recently, a new measurement of triggering has been reported by Collins et al. [3]. It used monochromatic x-rays from the SPring-8 synchrotron but for (several) much lower incident x-ray energies, in the 9- to 13-keV region. In order to verify this observation, we undertook a new measurement at the APS, specifically optimized for incident x-rays below 20 keV, as described below.

Methods and Materials

Several thin Hf isomer targets were prepared by electrodeposition onto Be disks. Two such disks were clamped together with the depositions adjacent (and the Be surfaces exposed) to make a "sealed" target. This target was irradiated by a white beam from a tapered undulator at SRI-CAT beamline 1-ID at the APS. The photons were collimated to a beam that was 1.4 × 2 mm^2, and the target was placed at 45° with respect to the incident beam. Gamma spectra were measured with a Ge detector placed at 90° and a distance of 22.9 cm. A set of Pb, Ta, Cd, and Cu absorbers covered the front face of the Ge detector. On the other side of the target chamber, a Si(Li) detector to measure x-rays was placed at 90°, 47.6 cm from the target center. A 0.05 × 0.05-mm^2 collimator placed in front of the Si(Li) detector reduced the counting rate to a manageable level. The purpose of the Si(Li) detector was to provide a measure of the Hf fluorescent K x-rays and, in turn, the beam luminosity. The incident x-ray beam was cycled: 11-second beam on-target followed by two 11-second counting periods with the beam off-target. We

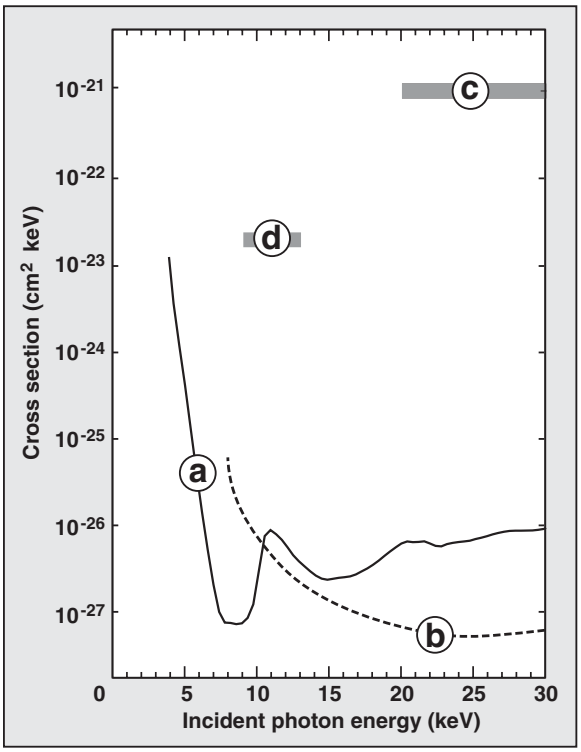

FIG. 1. Upper limit of the integrated cross section for x-ray-induced decay of the 31-yr ^{178}Hf isomer for incident energies 6 ≤ E_x (keV) ≤ 30 deduced from the present measurement [4] illustrated with a solid line (a). The limit from Ref. 2 is shown as a dashed line (b). For comparison, cross sections values reported in Refs. 1 and 3 are shown as crossed hatched bars (c and d). (See also results reported in Ref. 5.)

analyzed data as described in Ref. 2, that is, by taking the difference between beam-on and beam-off spectra. We have found no statistically significant difference in yield for ^{178}Hf gamma rays that were previously reported to show enhancement [1, 3] over a wide range of incident x-ray energies, which includes all incident x-ray energies for which triggered decay has been claimed. An upper limit to the energy-integrated cross section for triggered isomer decay is shown in Fig. 1. This limit for triggered decay is many orders of magnitude below values reported [1, 3] over the entire range of incident x-ray energies in question. More details of the APS investigation reported here are given in Ref. 4.

Preliminary survey experiments have been performed by another group [5] to examine the triggering of gamma emission from the 31-yr ^{178}Hf isomer. Intense monochromatic synchrotron radiation from the X15A beamline at the National Synchrotron Light Source at Brookhaven National Laboratory was used. Initial studies were performed to probe incident photon energies over the L x-ray edges of Hf and the 12- to 13-keV range. Resonances larger than the experimentally minimum detectable level of 10^{-25} cm^2 keV were not observed.

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