Resource Note on Photofission of Nuclei
for $^{235}\text{U}$ and $^{239}\text{Pu}$ Detection

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**ABSTRACT**

Open-source data exists, in widely scattered places, on photofission of the important nuclear isotopes $^{235}\text{U}$ and $^{239}\text{Pu}$. This data is useful for studies aimed at detecting these materials at ports of entry. An introductory survey is given to access that data.
1 Introduction

Mindful that it is now necessary to protect against the surreptitious importation of the nuclear materials $^{235}$U and $^{239}$Pu, various schemes are being proposed to detect them at borders. An example is that of Little et al. [1]. They are studying the use of a beam of photons, with energy of say $\leq 10$ MeV, to survey incoming freight and use the delayed neutrons from photofission of these nuclei as a signature of suspicious materials.

Therefore, existing data on (i) the photon cross-sections on these nuclei, (ii) photofission products, and (iii) the delayed neutron energy spectra are all of great interest. Although there exist classical, older surveys of data [2] - [5], it is important to collate more modern results.

2 Photon cross-sections on $^{235}$U and $^{239}$Pu

Modern experiments to measure the photofission cross sections for $^{235}$U and $^{239}$Pu began to produce results in 1980. The first success was by Berman’s collaboration, using $^{235}$U. The total cross section and the separate fission cross sections for 1, 2, 3 neutrons were obtained for photon energies up to 20 MeV [6]. (See especially Figure 2 of [6].) Further work was also done on the photoneutron multiplicities from monoenergetic photons from 5.5 to 18 MeV [7].

A later effort by the same collaboration produced similar results for $^{239}$Pu [8]. For example, in Figure 7 of [8] the total cross section and the separate fission cross sections for 1, 2, 3 neutrons for photon energies up to 20 MeV are given.

These and other results are compiled in the modern version of Ref. [5], the “Atlas of Photoneutron Cross Sections Obtained with Monoenergetic Photons” [9].
3 Photofission products

$^{235}\text{U}$: Starting in 1976 [10], a great deal of work on the photofission products of $^{235}\text{U}$ was done by the Belgium group in Gent, mainly in the 12-30 MeV photon energy range. There were detailed studies on the fragment mass distributions [11], the charge distributions [12], and on the isotopic and elemental yields [13]. As an example of the large amount of information in these papers, note that in table II of [13], the percentage elemental yields of Kr to Ha from $^{235}\text{U}$ are given. Isotopic information is also available.

More specific studies on the isomeric yield ratios for different elements were also done [14, 15].

$^{239}\text{Pu}$: Kinetic energy and fragment mass distributions from photofission on $^{239}\text{Pu}$ were also studied by the Gent group [16]. But in addition, almost simultaneously a study by a Russian group also appeared [17]. This gave element product yields from a bremsstrahlung beam of maximum energy up to 28 MeV. Both sources should be consulted.

Both $^{235}\text{U}$ and $^{239}\text{Pu}$: Later, there were two non-western studies on both nuclei. The first, from a Japanese group [18], was interested in the transmutation of high-level radioactive waste. It used 20, 30 and 60 MeV bremsstrahlung. They found results within 10% agreement with calculated values using published photonuclear cross-section data. Another study, by a Russian group from Obminsk, used photon energies up to 11 MeV. Their study found the yields for a number of odd nuclei, including both $^{235}\text{U}$ and $^{239}\text{Pu}$ [19]. These two studies and their included references are a valuable resource to an audience that might not be acquainted with this literature.

4 Delayed neutron energy spectra

The final category of critical information deals with the delayed neutron spectra from photofissioned $^{235}\text{U}$ and $^{239}\text{Pu}$. The literature is replete with many studies on this problem. See, e.g., Refs [20]-[25].

In addition, very recently, a program of measurements almost made to order has been
done by the French Atomic Energy Commission. They wanted to develop techniques to quantitatively assay low-level transuranics in bulk solid waste drums. This was first done by detecting on-line delayed neutron counting from incident photons with energies up to 18 MeV [26]. Soon after they did the same type of analysis, but this time with the delayed neutrons coming from the simultaneous interrogation of both photons and neutrons [27]. (They also interrogated Uranium encased in concrete [28].)

5 Comments

The literature presented here, and the literature contained therein, will serve as a background to programs like [1], which aim to study the detection of fissile materials from delayed neutrons. Data on neutron induced fission of nuclei $^{N-1}A$ [29]-[35] is also of interest as complementary data to the photofission of nuclei $^NA$.

Finally, all the available information on photofission is an aid to the evaluation of what type of light source is needed in the near future to best advance the field [36].

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