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by

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PHOTOFISSION OF Bi, W AND Ag FROM 300 TO 1000 MeV

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SUMMARY: The fission of Bi, W and Ag induced by (300 ÷ 1000) MeV photons has been studied. Nuclear emulsions, loaded with known amounts of suitable salts of the fissionable elements were used. The cross-section per photon and the fissility were obtained.

1. We briefly report here some experimental results on the fission of Bi,W, and Ag induced by photons of between 300 and 1000 MeV. We postpone to a later, more extensive paper, a detailed discussion both of the theoretical as well as experimental questions related to this investigation. The present paper is part of a systematic determination of fission cross-sections for heavy elements, induced by primaries of various natures and energies [1, 3].

2. The γ-ray source was the Frascati 1 GeV electron-synchrotron, one of whose beams was used to bombard loaded and unloaded Ilford K-0 nuclear emulsions. A loading technique developed [4] and by now extensively used by us allowed the introduction of a considerable amount of fissioning element into the bulk of the gelatin, as well as the accurate determination of the number of fissionable nuclei per square centimeter of emulsion. Suitable processing [4,5] eliminated all background problems and permitted rather heavy irradiation doses. Rather careful collimation precautions during the exposure, as well as a reliable scanning method served to reduce the usual sources of systematic errors. The dose measurement was carried out by means of the usual Wilson quantameters in use at Frascati. All the data needed for the determination of the photofission cross-sections at 1000 MeV are collected, as an example in Table I.

3. The general picture of the events found in the Bi-loaded plates is well described by the hystogram of Fig. 1, where the

Table I

Nuclide	Bi 209	W 184	Ag
Number of runs	3	2	1
Number of atoms cm^{-3}	$\sim 2.10^{20}$	$\sim 5.10^{20}$	10^{22}
Total number of tracks	$\sim$ 6000	$\sim$ 500	$\sim$ 100
Cross-sections per equivalent quantum, σ_Q, at 1000 MeV (millibarns)	12.2 ± 0.7	1 ± 0.1	0.1
Cross-sections per photon σ_k, between 300 and 1000 MeV (millibarns)	7.8 ± 0.8	0.65 ± 0.11	$\sim$ 0.05
Fissility	0.12	0.012	$\leqslant 0.0015$

range spectrum of the heavy tracks is shown. No doubts about the attribution of these tracks to Bi fission are possible.

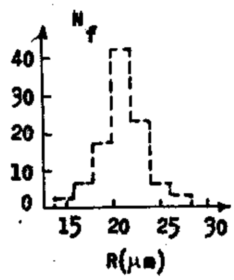

Fig. 1

The cross-section for photofission of W being relatively small, a considerable contribution to the total number of tracks in this case comes from heavy tracks due to fragments of the more abundant Ag and Br nuclei (see Table I). In order to determine this contribution, the unloaded plates were as well analysed. Figures 2a and 2b show the results: range spectra of heavy tracks found in W-loaded and unloaded plates are shown. The contribution of the W nuclei can be determined from the difference in the total number of tracks, and in their range distribution. The determination is substantiated by a careful analysis of the actual morphology of the observed events, taking into account both the frequency of noncollinear events (showing an angle $\leqslant 170^{\circ}$ between the two fragments) and the distribution of the ratio of the fragment ranges (see caption of Fig. 2). The general aspect of events is indeed very different.

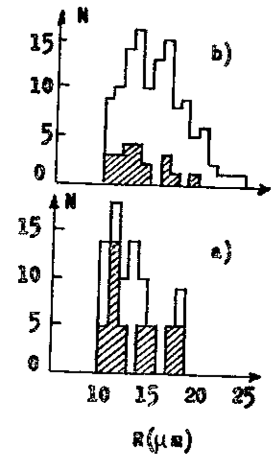

Fig. 2

The data from the unloaded plates should give information on the fission of the emulsion nuclei. The situation is complex however, first because at least two nuclear species (Ag and Br) can undergo fission, and, besides, because, as just remarked, the general aspect of events is different from that observed in the loaded pellicles so that the identification of any event as due to fission is no longer so clear-cut.

If one ignores this difference, and admits that all the events in the unloaded emulsions come from Ag nuclei (which is probably far from being the case) then one would get the fission cross-section of Ag nuclei. Due to the preceding observations, however, we can at most expect to obtain an upper limit for this cross-sections.

4. Figure 3 shows the Bi photofission cross-section per equivalent quantum, as obtained both in the present experiment as well as in previous experiments carried out by us [1] and by other authors [6,7]. The small discrepancy between our previous results and the present ones we think can be safely attributed to a systematic error (in the first experiment) due to the fact that, at the time, emulsions kindly loaded for us by Ilford Ltd. were used. Since they could be exposed only after several weeks of storage, it is probable that some of the loaded material was lost during that time.

The cross-section per photon of a given energy σ_k is obtained from the cross-section per equivalent quantum by taking the derivative of the latter with respect to log E. From Fig. 3 it is seen that σ_Q(Bi) is approximately linear over a wide energy range (300 to 1000 MeV), so that the slope of the best fitted straight line should be a good measure of σ_k(Bi) (see Table I). We define now the fissility as the ratio $f = \sigma_k/\sigma_{kt}$, where σ_{kt} is the total interaction cross-section. As will be shown in a next publication, σ_{kt} can be roughly obtained from the measured photo-star cross-section σ_{ks} (referred to the single nucleon) [8,9] by means of the equation

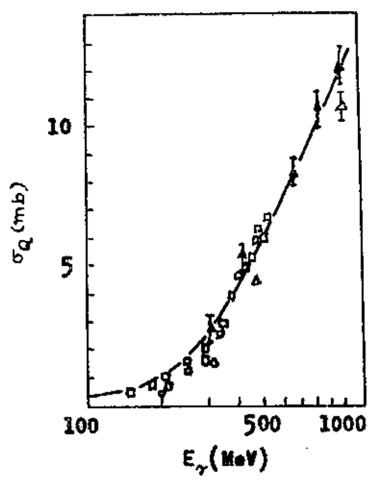

Fig. 3

$$\sigma_{kt} = 1.25\, A\sigma_{ks} ,$$

where A is the mass number of the considered nuclide. Observing that σ_{ks} is constant over the considered energy range, we find for the case of Bi

$$f_{Bi} = 0.12 \qquad ((300 \div 1000)\ \text{MeV}).$$

5. Figure 4 shows the W photofission cross-section per equivalent quantum. The scanty experimental data do not even warrant the linearity of σ_Q as a function of log E. A rough value of σ_k can however be obtained if, one assumes the fissility be constant over the (300 ÷ 1000) MeV energy range also in this case. Under such assumption it suffices to determine the constant factor by which the photostar cross-section per equivalent quantum should be multiplied in order to obtain a best fit to the experimental points. The slope of the straight portion of the line in the (300 ÷ 1000) MeV interval gives $\sigma_k(W)$ (see Table I). The fissility, calculated as in the case of Bi, comes out to be

$$f_W = 0.012 \qquad ((300 \div 1000)\ \text{MeV}).$$

6. An upper limit for $\sigma_k(Ag)$ will be obtained, as said above, considering all the events found in the unloaded pellicles as due to fissioning Ag nuclei. An assumed linear dependence of $\sigma_Q(Ag)$ on log E gives the $\sigma_k(Ag)$ value shown

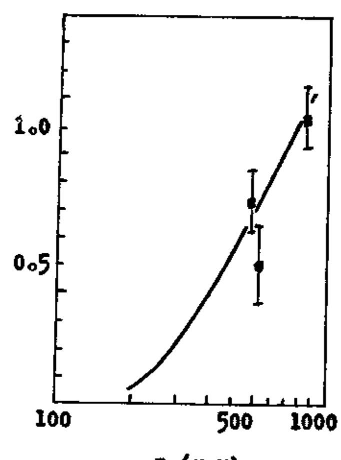

Fig. 4

in Table I. The fissility, found as for the other two elements, comes out to be

$$f_{Ag} \leqslant 0.0015 \ .$$

7. All the present results will be re-examined together with other photo-fission results (for U and Th) in a more extensive paper for which experimental work is still in progress.

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Captions to figures:

Fig. 1 - Range spectrum of the heavy tracks in the Bi-loaded plates exposed at 1000 MeV. Only collinear events (see text) were considered. $R = 20.6\ \mu m$.

Fig. 2 - a) Range distribution of events observed in W-loaded plates exposed at 1000 MeV. The shaded areas correspond to noncollinear events. b) The same distribution for the unloaded plates.

Fig. 3 - The Bi photofission cross-section per equivalent quantum, plotted against ln E. The data from Bernardini et al. [8] (circles), from Jungerman et al. [9] (squares) and from de Carvalho et al. [1] (open triangles) are shown, together with those obtained in the present work (full triangles).

Fig. 4 - The W photofission cross-sections per quantum equivalent at 600, 650 and 1000 MeV are given by the full squares. The data can be fitted roughly with a curve corresponding to a constant value of the fissility.

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