YIELD OF PHOTONEUTRONS EMITTED FROM LEAD UNDER THE ACTION OF 10.5 – 20.5 Mev ELECTRONS (THICK-ABSORBER METHOD)

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The yield of photoneutrons from a thick lead plate totally absorbing a monochromatic electron beam was measured. The experimental curve is compared with the theoretical curves computed with the aid of the Belen'kiĭ-Tamm equilibrium spectrum. The absolute energy calibration of the monochromator was based on the threshold of the (γ, n) reaction in oxygen and carbon.

PHOTONEUTRON yields for certain elements, calculated with the aid of the Belen'kiĭ-Tamm equilibrium spectrum, have already been given earlier.[1] The reasons for using the results of the cascade theory to estimate the number of photoneutrons produced under electron-accelerator conditions were also cited there (cf. also reference 2).

The purpose of the present work was the experimental determination of the phontoneutron yield from an essentially infinitely thick lead plate totally absorbing a monochromatic electron beam, and the comparison of the experimental and calculated results.

In setting up the present experiment, we have preserved the basic features of the experimental method proposed by Gol'danskiĭ and Shkoda-Ul'yanov[3] for the determination of photoneutron yields from thick blocks. We note that the results of reference 3 can also be used to estimate the possible number of photoneutrons in experiments with electron accelerators, albeit at higher energies than those considered in this paper.

Figure 1 is a schematic diagram of our experiment. Our experiment differs from that proposed earlier[3] by the fact that a monoenergetic beam of electrons, and not photons, falls directly on the investigated sample and has a bremsstrahlung spectrum. In this way, a Faraday cup can be used simultaneously as the electron-beam monitor and as the photoneutron source (cf. also references 4 and 5).

The linear accelerator of the Physico-Technical Institute of the Ukrainian S.S.R. Academy of Sciences, with a peak output energy of 30 Mev, operating with fifty 1-μsec current pulses per second, served as the electron source. The monoenergetic beam, 4, obtained with the aid of the magnetic monochromator, 1, located at the accelerator exit and with the aid of the collimator system, 2, was directed at the target, 8, placed at the center of a 80 × 80 × 80-cm paraffin cube. The first collimator, 2, similar to the one used by Brown and Wilson,[6] was a sectional cylinder with an outer diameter of 80 mm, and a total length of 450 mm, consisting of three sections; 150 mm aluminum, 200 mm graphite, and 100 mm lead. The inner opening had a 10 × 20-mm rectangular cross section. The second and third collimators, 4, were made of graphite and had an outer diame-

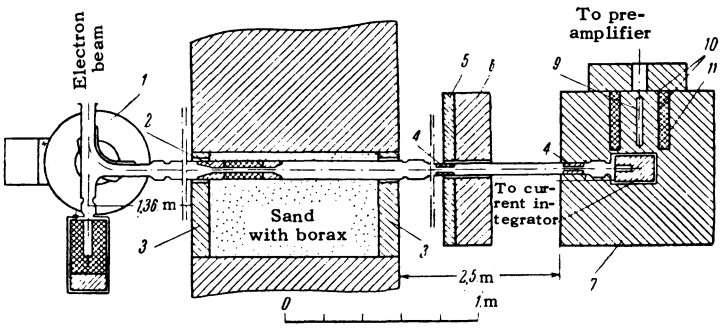

FIG. 1. Experimental setup (schematic).

ter of 50 mm, an inner-opening diameter of 20 mm, and a length of 200 mm.

The energy resolution of the beam extraction system was 0.4%. The target was placed at a distance of 5 m from the monochromator. The collecting collimator was set in a wall aperture and surrounded by sand with an admixture of borax and by a lead shield, 3. Additional shields of lead, 5, and paraffin, 6, were placed around the graphite collimator.

The boron counter, 9, similar to the one proposed by Hanson and McKibben,[7] was used to measure the neutron yield. The counter was placed inside the paraffin cube, 7, and was in addition surrounded by a 50-mm thick boron oxide layer, 11, and by a 2-mm thick cadmium layer. A special electronic circuit switched on the counter only during the time interval between the pulses of the accelerator current, with a 1.5-μsec delay. This made it possible to avoid counting the gamma quanta and to get rid of the electromagnetic disturbances appearing during the pulse.

The neutron counter worked in the region of direct proportionality between the neutron count and the current incident on the target. The measurements were carried out with currents on the order of 10^{-10} amp.

To determine the absolute photoneutron yield, the counter was calibrated against a standard Ra + Be source with a yield of $4.88 \times 10^5 \pm 3\%$ neutrons/sec.

The investigated target, 8, was made in the form of a Faraday cup, whose thick portion, serving as the photoneutron source, had a thickness on the order of 20 radiation units. Thus, the incident electron beam was practically completely absorbed in the investigated target (cf. also references 3 and 5). The Faraday cup was carefully isolated from the vacuum jacket in which it was placed, and was connected by means of a coaxial cable to the precision electron-current integrator, which served as a negative-feedback dc amplifier (cf. also references 8 and 5).

Figure 2 shows the measured photoneutron yield from a thick lead plate as a function of the electron energy in the interval from 10.5 to 20.5 Mev (curve 2), and also the neutron yield curves, 1 and 3, calculated with the aid of the Belen'kiĭ-Tamm equilibrium spectrum in accordance with the excitation functions of the photoneutron reaction in lead.[9,10] The points for curve 2 were registered in the 150- to 400-kev energy interval. Each point is the result of 5 — 7 measurements. The statistical spread of the pulse count did not exceed 2%. The background was measured by removing the Faraday cup, and amounted to 0.5% for energies below and not more than 3% for energies above the threshold of the (γ,n) reaction in carbon. In the latter case the neutrons were mainly produced in the graphite collimator, 4 (Fig. 1).

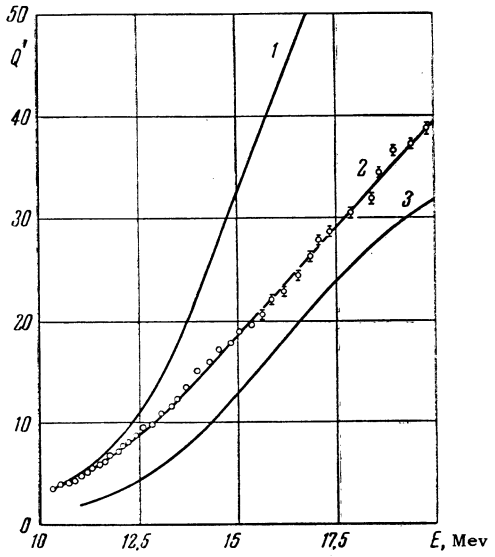

FIG. 2. Photoneutron yield (Q′) as a function of the electron-beam energy. To determine the absolute value of the yield (per electron), Q′ must be multiplied by 10^{-4}.

The absolute energy calibration was against the (γ,n) reaction threshold in oxygen and carbon by the activation method; samples of beryllium oxide and polystyrol were used for this. We estimate the calibration accuracy at about 100 kev.

As can be seen from Fig. 2, our experimental data are in better agreement with the results of reference 10 than with those of reference 9. Apparently, the values given in reference 9 for the function of photoneutron production in lead are much too large. Comparison of the experimental and theoretical photoneutron yields in lead permits us to conclude that the Belen'kiĭ-Tamm equilibrium spectrum can be successfully used for the purposes cited in reference 1. True, one must bear in mind that for certain elements the excitation functions of the photoneutron reaction, measured by different authors, give considerably differing absolute values (cf. references 9 and 10).

Following earlier ideas,[3] we have also estimated the integral cross section for photoneutron production in lead, and obtained a value of 2.6 b-Mev. We assumed that the energy for which the cross section attains its maximum value is 13.8 Mev. Our integral cross section agrees with the value of reference 10, 2.17 b-Mev. With the available data on photoneutron yields[4] it is also possible to determine the excitation function of the photoneutron reaction in the investigated element.

However, to obtain reliable results in this case, it is necessary to measure the energy dependence of the photoneutron yield with greater precision and for smaller energy intervals, in view of the need of determining the first and second derivatives.

At present we are making some improvements in the experimental methods. These will obviously not change appreciably the absolute value of the measured yield, but will, we hope, permit a sufficiently precise calculation of the excitation function of the photoneutron reaction in lead from the photoneutron yield curve.

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