EXCITATION FUNCTION FOR THE (γ, p) *REACTION ON TUNGSTEN*

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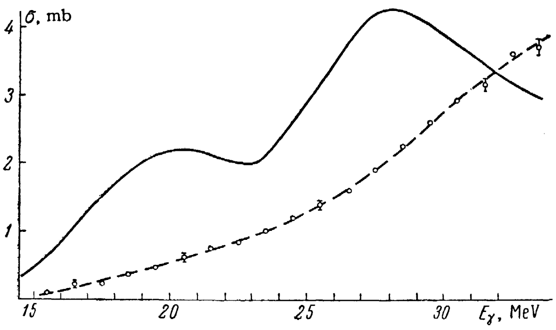
The yield of the (γ, p) reaction on tungsten is measured for $E_{\gamma max}$ between 15.5 and 33.5 MeV by recording photoprotons with a CsI(Tl) crystal scintillation spectrometer. The dependence of the (γ, p) cross section on the γ-quantum energy derived from the yield curve by the Penfold-Leiss matrix method exhibits maxima at ~20.5 MeV (2.2 mb) and ~28 MeV (4.3 mb). An analysis indicates that the more pronounced peak at ~28 MeV is mainly caused by E2-absorption, whereas the 20.5 MeV peak is due to E1- as well as E2-transitions. The integral cross section for the (γ, p) reaction up to 33 MeV is 50 ± 10 MeV-mb.

It was observed earlier [1,2] that the maxima of the cross sections of the (γ, p) reaction on heavy nuclei lie at energies above 22.5 MeV, and that the absorption of gamma quanta has in this region an essentially quadrupole character. It was deemed of great interest to measure the excitation functions of such reactions. For this purpose the yield of the (γ, p) reaction on tungsten was plotted in the interval from 15.5 to 33.5 MeV.

A collimated beam of bremsstrahlung gamma quanta from the 35-MeV betatron of the Nuclear Physics Institute of the Moscow State University was aimed at a tungsten target 49 mg/cm^2 thick, located in the vacuum chamber. The protons emitted from the target were registered with two scintillation spectrometers.

Direct registration of the products of photonuclear reactions on a betatron is hampered by the large electron and gamma background produced in the target and in the walls of the vacuum chamber. To attenuate the background, the gamma-ray beam passed through a carbon absorber 33.2 g/cm^2 thick, and the protons were registered 120 and 150° to the direction of the gamma beam. To reduce the amplitudes of the background pulses, thin (~1 mm) CsI(Tl) crystals were used, and to reduce the probability of superposition, the gamma-ray pulse from the betatron was stretched to 120 and 150 microseconds. Only protons with energy larger than 7 MeV were registered.

The yield curves measured at 120 and 150° were corrected after subtraction of the background, with allowance for the angular distribution of the photoproton [2], in order to obtain the total yields. The average of two such series of values of total yields are shown in the figure. The registered



Measured reaction yields (in relative units). A smoothed yield curve is drawn through the experimental point (dashed). The excitation function $\sigma(E_\gamma)$ is represented by the continuous curve.

number of protons ensured a statistical accuracy of 7—8 per cent in the initial part of the curve, rising to ~2.5 per cent at energies above 25 MeV. After the usual operation of smoothing, the excitation function of the (γ, p) reaction on tungsten, also shown in the figure, was calculated with the aid of the Penfold and Leiss [3] matrix method. The excitation function has one clearly pronounced maximum at ~28 MeV, with a value $\sigma \sim 4.3$ mb, and a much less pronounced maximum at ~20.5 MeV, with a value $\sigma \sim 2.2$ mb. At the measurement accuracy attainable in the region up to 25 MeV, the existence of a maximum at ~20.5 MeV cannot be regarded as completely demonstrated, but the acute slowing down of the decrease in the cross section with decreasing E_γ from ~24 to ~19 MeV is beyond doubt.

From a comparison with the results obtained from the angular distributions [2] it is seen that the maximum at ~28 MeV is due essentially to E2 transitions and represents a unique quadrupole resonance, whereas a considerable part ($\gtrsim$60 per cent) of the cross section in the region below 22.5 MeV is due to electric dipole transitions. On this basis, we can also understand the shape of the obtained cross section curve. The most intense E1 transitions, as is well known, are observed in the region of giant resonance, that is, at 13—15 MeV. However, the energies of the direct resonant photoprotons produced in these transitions are sufficiently small, and their yield turns out to be completely suppressed, owing to the large value of the Coulomb barrier of the tungsten. At higher energies, the intensities of the E1 transition decrease, but since the photoproton energies increase, the emission probabilities and the cross section of the (γ, p) reaction increase to a maximum in the region ~20.5 MeV. At still higher energies, the intensities of the E1 transitions begin to drop much faster, whereas the penetrance already increases slowly, and this leads to a decrease in the cross section for the production of the photoprotons due to E1 absorption. At these energies, however, E2 absorption sets in and contributes to the photoproton production, as a result of which the summary cross section of the (γ, p) reaction in the 21—24 MeV region hardly decreases. Finally, at energies above 25 MeV, the most intense E2 transitions come into play, producing quadrupole resonance with the maximum at ~28 MeV.

It must be noted that when Z is increased, the maximum of the dipole cross section of the (γ, p) reaction will shift toward the higher energies, owing to the increase in the Coulomb barrier, whereas the maximum of the quadrupole resonance shifts toward the lower energies, as a result of which the positions of these maxima should almost coincide for the heaviest nuclei. This is precisely the picture observed in the case of lead, where the cross section of the (γ, p) reaction shows only one maximum at ~26 MeV[4,5].

The integral cross section of the (γ, p) reaction on tungsten up to E_γ = 33 MeV amounted to 50 ± 10 MeV-mb, the integral cross section being ~30 MeV-mb in the region of the quadrupole resonance from 24 to 33 MeV. This value is close to the result obtained for lead, and does not contradict the estimate based on the sum rule for E2 transitions[6] (~0.45 MeV-mb), if it is recognized that an appreciable fraction of the quadrupole transitions leads to the emission of neutrons, owing to the mixing of the configurations.

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