Total cross section for the absorption of γ quanta by Th^{232}, U^{235}, U^{238}, and Pu^{239} in the region of dipole giant resonance

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We consider the evolution of the form of the photodisintegration cross sections of the nuclei Th^{232}, U^{235}, U^{238}, and Pu^{239}, measured by the absorption method, as Z varies from 90 to 94. The observed change in the form of the cross section is connected with the properties of the nuclear surface.

As demonstrated in a number of studies,[1,2] nuclei with approximately 90 neutrons exhibit a rapid variation of the surface properties with changing N. This becomes manifest, in particular, in an increase of the mean-squared deformation of the ground state with increasing N, which leads to an abrupt change in the form of the photoabsorption cross section.

An analysis of the characteristics of the low-energy excited states of the nuclei Th^{232}, U^{235}, U^{238}, and Pu^{239}, which have Z close to 90, shows that all these nuclei have a large equilibrium deformation in the ground state. At the same time, with increasing Z these nuclei exhibit a certain systematic increase of the deformation parameter β and a decrease in the parameter μ of softness with respect to surface oscillations.[3] It is of considerable interest to investigate how these properties of the aforementioned nuclei can influence the form of their photoabsorption cross section. Such information is capable of providing additional material with which to verify the validity of the existing collective models of the nucleus.

We measured the total cross sections for the photodisintegration of nuclei with $Z \approx 90$ by the method of absorption with a bremsstrahlung beam from a synchrotron with maximum accelerated-electron energy up to 35 MeV. The use of the absorption method has made it possible to take into account uniquely, for the first time, the contribution made to the total cross section by all the partial reactions; this is a formidable problem in other measurement methods, owing to the existence of a strong photofission channel. The experimental set-

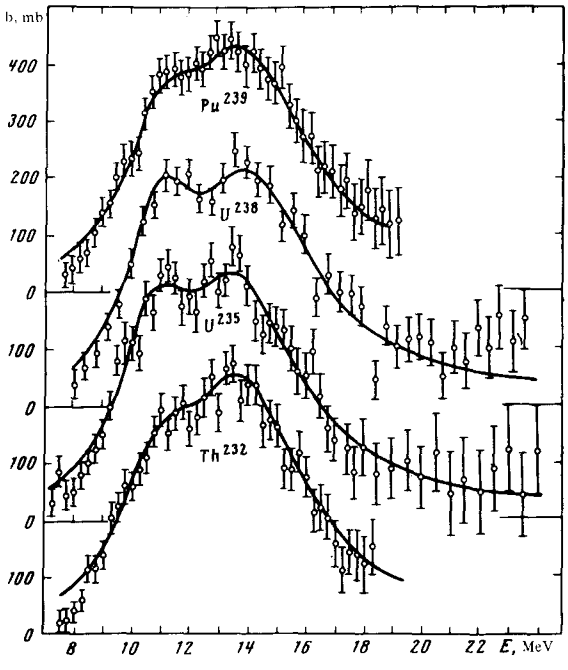

FIG. 1.

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[illegible] parameters for the approximation of the cross section by Lorentz lines.

Nucleus	σ_1 mb	Γ_1 MeV	E_1 MeV	σ_2 mb	Γ_2 MeV	E_2 MeV	$\frac{\sigma_2\Gamma_2}{\sigma_1\Gamma_1}$	β	Q
Th^{232}	247	3.90	10.99	362	4.67	13.9	1.75	0.28	10.0
U^{235}	283	3.23	10.74	354	4.92	13.77	1.91	0.30	11.0
U^{238}	286	2.99	10.97	351	5.10	14.25	2.09	0.31	11.7
Pu^{239}	227	3.47	11.05	362	5.23	14.01	2.40	0.29	11.0

up and the procedure are analogous to those described in[4].

The measured nuclear photoabsorption cross sections are shown in Fig. 1. The mean-square errors are indicated. All the curves reveal a splitting of the giant resonance into two maxima, which is typical of strongly-deformed nuclei. The measured cross sections were approximated by least squares with two Lorentz lines. The approximating curves are shown in Fig. 1 by solid lines. The approximation parameters are listed in the table. The parameters obtained for Th^{232} and U^{238} agree quite well with the results of Bergere's group,[5] which were obtained by summing the cross sections of the reactions (γ, n), $(\gamma, 2n)$, and (γ, F). The photoabsorption cross section for U^{235}, measured by Bowman *et al.*,[6] exceeds appreciably the cross section obtained in the present paper.

The ratios $\sigma_2\Gamma_2/\sigma_1\Gamma_1$ of the areas under the high-energy and low-energy peaks in the cross section are close to the value 2 that follows from the dipole sum rule for an elongated spheriodal nucleus. The observed increase of these ratios with increasing Z can be attributed to an increased rigidity, described by the parameter μ, of the nucleus relative to longitudinal oscillations. The last two columns of the table give the effective parameters of the deformation and the quadrupole moments of the nuclei, calculated from the ratios E_2/E_1 using the optical-anisotropy model proposed by Danos.[7] The values of β, as expected, agree well with the values of the mean-squared deformation parameter obtained from the probability of excitation of the first 2^+ level. A comparison with the results of[8], where the values of the deformation parameter were calculated for different models of nuclear density on the basis of data on the Coulomb excitation of the nuclei Th^{232} and U^{238} by particles, shows that the best agreement with the data presented above is obtained for the model of charge distribution with diffuse boundary, characterized by a half-value radius $r_0 = 1.1$ F and a surface-layer thickness $a = 0.6$ F.

Figure 2 shows the behavior of the widths of the giant resonance for the investigated nuclei (solid curve), and also widths from[5] (triangles). The systematic increase of the width with increasing Z agrees with the increase of the optical anisotropy of the nuclei. The dashed line shows the calculated values of the widths obtained with the aid of the semiempirical formula of[9]

$$\Gamma = 0.026\,E^{1.9} + 0.76E\beta - 0.82\,E_{2^+}\ , \qquad (1)$$

where $E = E_1/3 + 2E_2/3$, and E_{2^+} is the energy of the first excited 2^+ state. A comparison with the experimental and calculated widths shows that the semiempirical formula (1) describes on the whole correctly the character of the change in the widths obtained in the present paper with increasing A. The results of[5] do not agree with this relation.

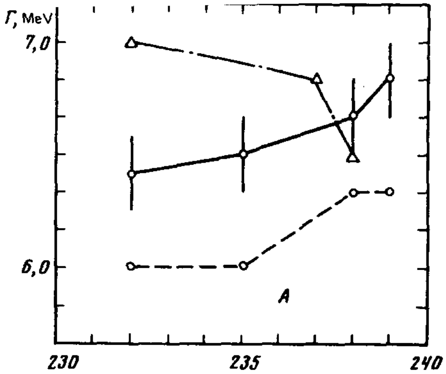

FIG. 1.

The total cross section for the nuclei U^{235} and U^{238} was measured up to ~25 MeV. The large experimental errors in the region $E > 19$ MeV precludes a discussion of the form of the cross section in this region. However, as seen from Fig. 1, the cross section does not fall to zero but lies above the Lorentz line and remains on the average at the ~100 mb level. This does not contradict the assumed existence of a contribution of quadrupole absorption in the energy region 20—25 MeV.

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